APPENDIX 12

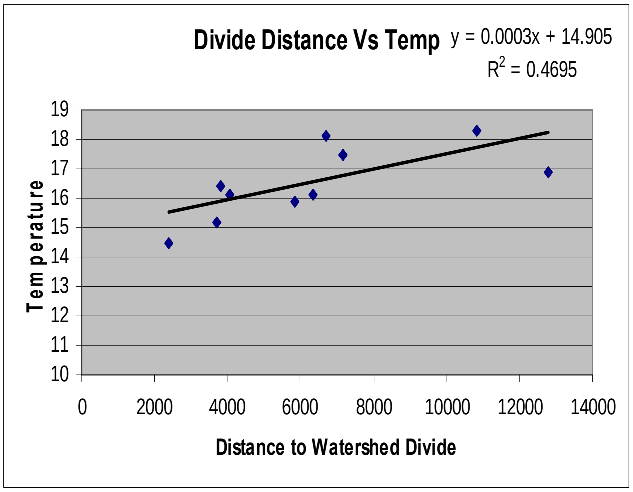
STREAM TEMPERATURE

Background

Water temperature is an important habitat parameter potentially influencing reproductive success and survival during all freshwater life stages for coho salmon, steelhead, and many amphibians, aquatic macro-invertebrates, and other organisms (Bjornn and Reiser 1991). Water temperature influences metabolism, behavior, and mortality of fish and other organisms in their environment. Coho salmon tend to be relatively intolerant of elevated summer water temperatures and may therefore be absent from streams that can still support steelhead. Although fish may survive at temperatures near the extremes of the suitable range, growth is reduced at low temperatures because all metabolic processes are slowed and at high temperatures because most or all food energy must be used for maintenance (Bjornn and Reiser 1991).

Stream temperature is influenced by external factors, the internal structure associated with channel morphology, and the riparian zone. The internal factors are reduced vegetative shading (allowing more solar radiation to reach streams), changes in channel morphology, altered streamflows, and heating of unvegetated near-stream soils and alluvial substrates (Poole and Berman in press, Johnson and Jones 2000). The external factors include: topographic shade, upland vegetation, precipitation, air temperature, wind speed, solar angle, cloud cover, relative humidity, phreatic groundwater temperature, tributary temperatures and flow (Poole and Berman 2000). In addition, water temperatures generally increase in a downstream direction even in fully shaded streams (Sullivan et al. 1990). As streams become progressively larger and wider, riparian vegetation shades a progressively smaller proportion of the water surface (Beschta et al. 1987; Spence et al. 1996; Murphy and Meehan 1991). Figure 1 illustrates how stream temperatures in a watershed tend to increase in the downstream direction and increase with increasing watershed area.

Land management activities can influence water temperature by exerting changes on channel characteristics (Table 1). In forested landscapes, incoming solar radiation represents the dominant form of energy input to small and medium size streams during the summer months (Bescheta 1987, Sullivan et al. 1990). Canopy cover is important in reducing direct solar radiation to the channel and can be directly influenced by forest management. Removal of a streamside riparian canopy typically increases solar radiation intensity, summer water temperature, and diurnal temperature fluctuations throughout the year (Chamberlin et al. 1991, Hetrick et al. 1998). Removal of too much canopy can adversely affect growth and survival of rearing salmonids. The more canopy removed, the greater the exposure to solar radiation, which then increases stream temperature.



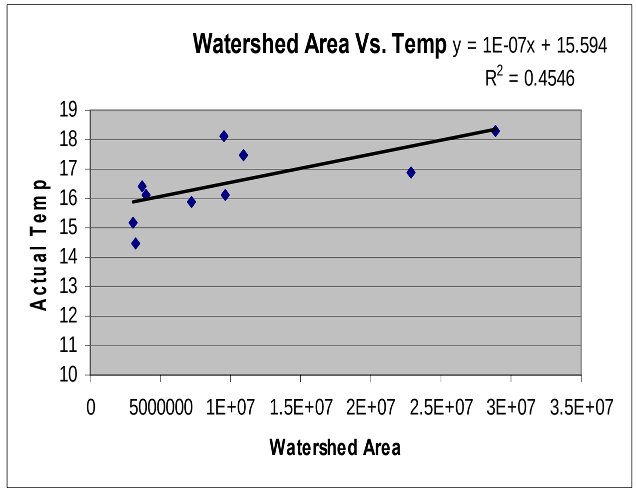


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Figure 1. Relationship between Divide Distance (meters) and Stream Temperature (ºC) (A) and Watershed Area (meters^2) and Stream Temperature (ºC) (B).

Table 1. Associated Human Influences on Processes that Affect Water Temperature.

PROCESS AFFECTING WATER TEMPERATURE	HUMAN INFLUENCE
Increased phreatic groundwater discharge	Removal of upland vegetation
	Water withdrawals for irrigation / municipal use
Reduced stream flow	Water withdrawals
Hydrology and Channel Morphology	Dams; reduction in peak flows
	Dikes and Levies
	Riparian management; removal of LWD
Changes in channel morphology – wider streams, channel aggradation	Management activities; increased sedimentation
	Dams; removal of peak flows
Riparian canopy cover	Riparian management; influences on shade

(Modified from Poole and Berman 2000.)

Conversely, riparian vegetation also limits light penetration to a stream and may suppress aquatic primary productivity (Murphy and Meehan 1991). Planned openings along cold, closed canopy coastal streams can improve periphyton production, leading to increased aquatic invertebrate abundance and subsequently enhance fish productivity if other habitat requirements are maintained (Murphy and Meehan 1991; Chamberlin et al. 1991; Hetrick et al. 1998). However, cumulative effects of increased water temperature and sediment from numerous disturbances in a watershed can nullify any beneficial effects of increased food production (Murphy and Meehan 1991). Therefore, timber harvesting activities in riparian zones need to be carefully planned if improved salmonid production is desired.

There is uncertainty regarding the optimal riparian buffer to shade a stream, or whether there is any single configuration that is most beneficial or desirable. The relative degree of shading provided by a buffer strip depends on species composition, age of stand, density of vegetation, and sun angle. Spence et al. (1996) concluded buffer widths of approximately 0.75 site potential tree heights are needed to provide full protection of stream shading. FEMAT (1993) reported that nearly all shade to a stream can be maintained by a buffer width equal to approximately 0.8 potential tree height. According to the Record of Decision for FEMAT (FEMAT ROD 1994), a site potential tree equals the average maximum height of the tallest dominant trees (200 years or older) for a given site class. For a coast redwood on Site I or II land, it is likely that a “mature” tree would be at least 250 feet tall.

In a comprehensive review of the FEMAT (1993) standards, CH2M-Hill and Western Watershed Analysts (1999) reported that nearly 80 percent of the cumulative riparian shade effectiveness is reached within approximately 0.5 site-potential tree heights (e.g., for a 250 foot site potential tree, this distance would be 125 feet, 25 feet less than the current width of a Class I WLPZ). Beschta et al. (1987) and Murphy (1995) state that buffer strips with widths of 30 m (approximately 100 feet) or more generally provide the same level of shading as that of an old-growth stand.

The stream temperature at any given point can be taken as an indicator of the cumulative spatial and temporal effects of numerous factors upstream of that point. As discussed above, there are numerous natural and anthropogenic factors that determine stream temperature. Since stream temperature is such a robust cumulative effect indicator, it is an important parameter to measure on an ongoing basis. It is also important to try to understand the state, over space and time, of the determinants of temperature. Stream canopy is one of the most important and most readily measurable of stream temperature determinants. It also is a stream temperature determinant that has been significantly affected by land management activities in the North Coast region since the last half of the 19^{th} century.

Regulatory Setting and Regional Context for Use of the MWAT Criterion for Assessing Impacts

The North Coast Regional Water Quality Control Board (NCRWQCB) is responsible for implementing and regulating water quality control plans for the North Coast Hydrologic Unit Basin Planning Area. The Basin Plan provides a definitive program of actions designed to preserve and enhance water quality and to protect beneficial uses of water. The US EPA and NCRWQCB have identified 22 North Coast water bodies as having beneficial uses impaired by elevated water temperatures (Table 2). These water bodies, with a total watershed area of 8.7 million acres, are listed as temperature impaired under section 303(d) of the federal Clean Water Act.

Table 2. Temperature Impaired Water Bodies and Watershed Area in the North Coast Hydrologic Unit.

Water Body	Watershed Area (acres)	Water Body	Watershed Area (acres)
Big River	115,840	Shasta River	505,542
Eel River (6 units)	2,356,802	Russian River	949,986
Garcia River	73,223	Klamath River (including)	
Gualala River	191,145	*Salmon River*	480,805
Redwood Creek	180,700	*Scott River*	521,086
Ten Mile River	76,800	*South Fork Trinity River*	596,480
Mattole River	189,440	*Upper & Lower Lost River*	1,917,782
Navarro River	201,600		
Mad River	322,200	**TOTAL AREA**	**8,679,431**

The NCRWQCB has listed Big River for temperature and sediment. The Noyo is listed for sediment, but not temperature, although reaches of the Noyo are subject to relatively high water temperature, especially in the main channel. This impairment designation is assigned to streams where established water quality objectives as specified in the Basin Plan are not being met or where beneficial uses are not sufficiently protected. Total Maximum Daily Loads (TMDLs) must be developed for water quality listed streams, as required in Section 303d of the Clean Water Act (CWA). A TMDL is a planning document designed to identify the causes of impairment and establish a framework for restoring watershed impairments. Sediment TMDLs have been developed for both the Noyo and Big River, but a temperature TMDL has not yet been developed for the Big River watershed, nor has a completion date for one been specified.

MWAT Threshold and Criteria for Determining Impairment

Water temperature suitability for anadromous salmonids in the North Coast region can be evaluated using the maximum weekly average temperature (MWAT). MWAT is defined as the highest average of mean daily temperatures over any 7-day period. The MWAT threshold is a measure of the upper temperature recommended for a specific life stage of freshwater fish (Armour 1991). For coho salmon and steelhead, the MWAT threshold is calculated for the late-summer rearing life stage, because water temperatures are generally highest during this stage. Coho salmon are considered to be less tolerant of high water temperatures than steelhead (CDF 1999).

A range of MWAT values has been proposed by different agencies and through independent studies to identify appropriate threshold values (Table 3). For the JDSF EIR, an MWAT value of 16.8°C (62.2°F) was chosen as a threshold of significance to evaluate potential impacts to water temperature that are associated with the proposed project. The National Marine Fisheries Services originally established 16.8°C as an MWAT threshold for coho (NMFS and USFWS 1997). This threshold is supported with recent findings by Welsh et al. (2001), where researchers found juvenile coho present in 18 of 21 tributaries of the Mattole River with MWATs up to 16.7°C (62.1°F). They also found coho in all streams where MWATs were less than 14.5°C (58.1°F). Similarly, Hines and Ambrose (2000) collected water temperature and coho salmon data over a five-year period from 1993 to 1997 at 32 sites in coastal streams of western Mendocino County, including 4 sites in the Noyo and Big River watersheds. Their data showed that the number of days a site exceeded an MWAT of 17.6°C (63.7°F) was one of the most influential variables for predicting coho presence and absence.

Table 3. A range of known MWAT thresholds and standards for salmonids (source: NCRWQCB 2004).

MWAT Thresholds and Standards		
Temperature (C)	**Descriptions**	**Temperature (F)**
26	Upper end of range of acute thresholds (considered lethal to salmonids)	78.8
25		77.0
24	Lower end of range of acute thresholds (considered lethal to salmonids)	75.2
23		73.4
22		71.6
21		69.8
20		68.0
19	Steelhead growth reduced 20% from maximum (Sullivan and others, 2000).MWAT metric USEPA (1977) growth MWAT for rainbow trout	66.2
18	USEPA (1977) growth MWAT for coho	64.4
17	Steelhead growth reduced 10% from maximum. Coho growth reduced 20% from maximum (Sullivan and others, 2000), MWAT metric	62.6
16.8	**NMFS MWAT threshold.**	**62.2**
16.7	Welsh and others (2001) MWAT threshold for coho presence/absence in the Mattole	62.1
16	Oregon Dept. of Environmental Quality Standard for salmonids (equivalent MWAT calculated from 7-day max.)	60.8
15	EPA Region 10 Recommended MWAT. Threshold for Coldwater Salmonid Rearing	59.0
14.8	Coho growth reduced 10% from maximum (Sullivan and others, 2000), MWAT metric	**58.6**
14.6	Upper end of preferred rearing range of coho	58.3
14.3	Washington Dept. of Ecology standard (equivalent MWAT calculated from annual max.)	57.7
14		57.2
13	Upper end of preferred rearing range for steelhead.	55.4

The Recovery Strategy for Coho Salmon (Department of Fish and Game 2004) makes only a generic range-wide recommendation regarding stream temperature. That is, “Identify and implement actions to maintain and restore water temperatures to meet habitat requirements for coho salmon in specific streams,” (recommendation RW-X-B-01).

Logging History and Water Temperature

The stream channels and watersheds within and surrounding JDSF have a long and varied history of logging, railroad, and road construction. Beginning in the 1850s, Big River was used as a log transport route to get logs to the sawmill located near the mouth of the river. The Noyo River has a similar history, although railroad transport was dominant in that drainage (Wurm 1986). In the Noyo River, there is evidence that river transport occurred between the 1860s and the very early 1900s (Marc Jameson, CDF, Fort Bragg, personal communication).

Before the development of railroads in and along coastal waterways, trees were felled and moved to the river channels by use of both hand and animal labor (Napolitano and others 1989). In the Big River drainage, animals, primarily oxen, were used for yarding of logs until 1914 (Jackson 1991). The logs were dragged downhill and dumped into the river. In order to facilitate water transport, the channels were often cleared of logs, stumps, debris, and standing trees that were capable of interfering with transport and resulting in logjams. River transport in Big River continued over a period of nearly 70 years, between 1850 and 1930, using 27 splash dams to facilitate the floating of logs downstream to the mill at the town of Mendocino (Jackson 1991) (Figure 2). South Fork Big River is heavily incised from flushing logs. The dams varied in size and construction methods, but ranged to as tall as 40 feet. Many of the dams were designed to operate in a synchronized fashion to maximize the flow of water in downstream reaches.

The actual process of logging removed most, if not all, of the old-growth trees growing along the streams, which probably resulted in large increases in direct solar radiation striking the channel and coincident substantial increases in water temperature. This effect was accentuated with the development of railroad technology. Railroad grades were constructed immediately adjacent to river channels, and often constructed directly within the channels (Wurm 1986). Along with the railroads, steam yarder technology enabled efficient clearcutting of vast tracts upslope and adjacent to the river and stream system, with logs generally pulled downslope within or adjacent to watercourses along their route to the rail line. This activity created large openings along waterways, in addition to massive erosion into the channels, creating wide, unshaded streambeds with aggradation and elevated water temperature.

Railroad logging was replaced by trucks and tractors, beginning in the 1920s, with the railroads being all but eliminated by the mid-1940s (CDF 2003, Wurm 1986). Early road construction and tractor yarding provided no stream protection. Roads were constructed immediately adjacent to, or within stream channels. Logs were yarded downslope by tractor, often being moved directly within stream channels to reduce the amount of excavation required during the yarding process. Log landings were commonly constructed within tributary channels during this period. All of these activities tended to reduce shade-producing canopy, resulting in elevated water temperature. There are numerous accounts by the Department of Fish and Game of stream damage and elevated water temperature within the Noyo and Big River watersheds (DFG stream survey files, Yountville).

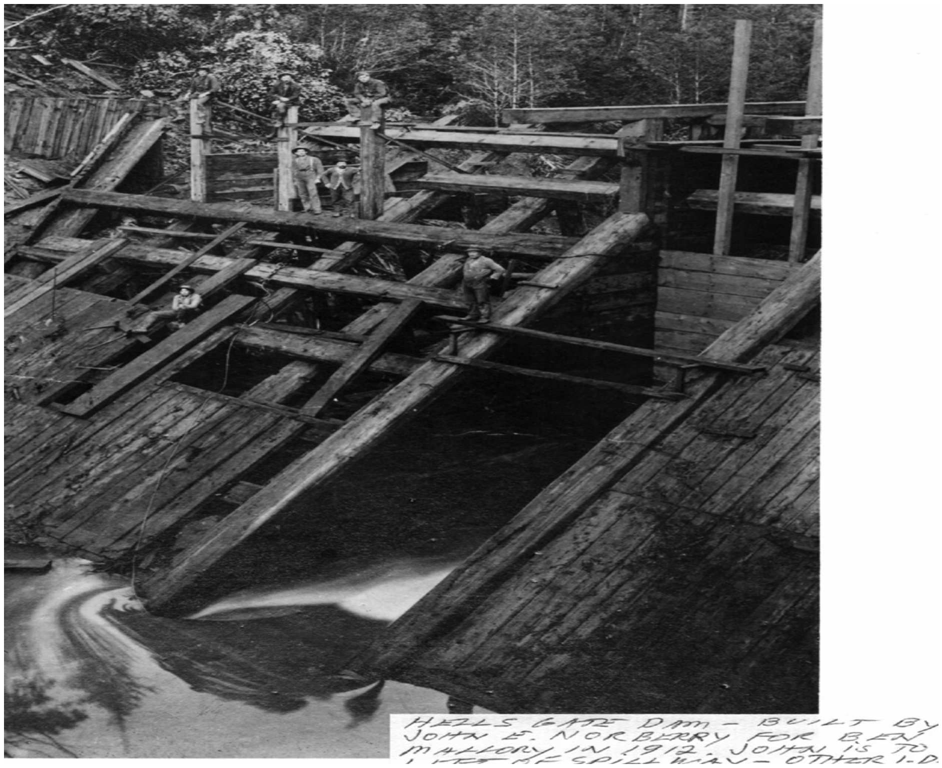

Figure 2. Hells Gate Splash Dam on the South Fork. Photo provided courtesy of the Mendocino Historical Society and the Held Poage Memorial Home and Research Library (from the Collection of Robert Lee).

There were no effective regulations in place to protect stream channels and shade-producing canopy until 1974, with the implementation of the Z'Berg Nejedly Forest Practice Act of 1973. The Forest Practice regulations of the mid-1970s provided for some consideration of stream protection, but it was still possible to substantially reduce shade canopy along fish streams. Streams were defined as natural watercourses--as designated by a solid line or dash and three dots symbol shown on the largest scale USGS maps most recently published, or as corrected in the THP map to reflect conditions on the ground. The Stream Protection Zone (SPZ) was defined as a strip of land along both sides of the watercourse for 100 feet for streams which supported and were used by trout or anadromous fish any time of the year, and 50 feet for any other streams or lakes. Enough trees had to be left so that 50% or more of the shade producing canopy present before timber operations remained after timber operations. Most, if not all of the shade-producing conifers could be removed if the forester could adequately explain how 50% of the shade would be retained.

It was not until 1983 that forest practice rules were enacted that required consideration of key indicator beneficial uses of water (fish, domestic water supplies for Class I watercourses, etc.), and it was not until the mid-1980s that cumulative impacts were expressly considered in the THP process. Protective zones were based on watercourse class and side slopes (0-30%, 30-50%, 50-70%, and >70%). The stream protection rules enacted substantially increased both the consideration of, and protection of, streamside canopy. In 1991, the rules were strengthened again. With the listing of both the Noyo River and Big River as impaired waterbodies, along with the listing of the coho salmon, rules have been substantially strengthened, and streamside canopy considerations have been further elevated. In July 2000, the implementation of the Threatened and Impaired Watersheds Rule Package greatly increased stream protection and post-harvest canopy levels. Proposals to reduce shade-producing canopy adjacent to Class I watercourses within the watercourse protection zone are not often encountered within the assessment area, and the level of shade-producing canopy should be increasing as riparian stands grow.

CDF's Hillslope Monitoring Program report for 1996 through 2001 found that watercourse protection zones retained high levels of post harvest canopy and surface cover (Cafferata and Munn 2002). Mean total canopy exceeded Forest Practice Rule requirements and was approximately 80 percent in the Coast Forest Practice District for both Class I and II watercourses. WLPZ width requirements were generally met, with major Forest Practice Rule departures recorded only about one percent of the time. Modified Completion Report monitoring conducted by CDF Forest Practice Inspectors from 2001 through 2004 similarly revealed that post-harvest total canopy levels were high (281 THPs sampled, 198 with Class I or II WLPZs) (Brandow 2005). Class I and II WLPZ total canopies averaged 83% and 82%, respectively, for the Coast Forest Practice District. These numbers are very similar to those recorded for the earlier Hillslope Monitoring Program. Similar measurement techniques were used by both monitoring efforts. As the streamside forest continues to develop within the assessment area, water temperature should take steady progress toward levels favorable to fish.

Watershed Setting and Regional Context for Stream Temperature

The JDSF ownership covers portions of both the Noyo and Big Rivers (see Map Figure A). The South Fork of the Noyo River (SFNR) and North Fork of the Big River, including Chamberlain and James Creeks, are the primary watersheds that drain the forest. The SFNR is a major tributary to the Noyo River, which drains to the Pacific Ocean at Fort Bragg. The SFNR catchment area at the confluence with the Noyo River drains a 27.32 mi^2 area, which is approximately 35% of the entire Noyo River watershed (113 mi^2). The vast majority of SFNR is owned and managed by JDSF. As such, management activities contribute to the overall water quality conditions in the lower Noyo, below its confluence with SFNR. The SFNR basin is characterized by steep mountainous terrain with confined valleys. The headwaters of the SFNR have more moderate terrain.

The Big River drains a 181 mi^2 watershed, flowing into the Pacific Ocean at the town of Mendocino. The elevation ranges from sea level to 1556 ft and consists of moderate to extremely rugged terrain (Matthews, 2001). Chamberlain and James Creeks are major tributaries to the North Fork of the Big River. The majority of these tributary watersheds are public lands managed by JDSF. The headwaters of the North Fork of Big River are private forest land and reside upstream from the JDSF boundary. Water from the Upper North Fork Big River flows through JDSF, passes through private forest in the Lower North Fork of the Big River, before joining the mainstem of the Big River.

CDF has conducted comprehensive summer water temperature monitoring in streams throughout JDSF since 1993, as well as temperature monitoring in the Caspar Creek watershed since the mid-1960s. Overall, water temperatures in JDSF Class I watercourses are generally in the suitable range for coho salmon and steelhead, with a few exceptions (CDF 1999). The areas of concern that are potentially impacted by JDSF land management are located on the South Fork of the Noyo River and Chamberlain Creek, tributary to the North Fork of Big River.

Stream temperature data are collected widely across the Noyo and Big River watersheds (Figure 3). Stream temperature issues were analyzed using data collected by state agencies (CDF, NCRWCQB, and DFG, and landowners) and supplemented with data from the KRIS Noyo and Big River projects (see http://www.krisweb.com). A summary of the data used in this assessment is provided in Attachment A. While water temperature is of concern for both watersheds, Big River has recorded warmer temperatures, leading to its inclusion on the U.S. EPA's 303(d) list as temperature impaired. The spatial distribution of water temperature was mapped out across the entire assessment area to identify areas of concern that may require more detailed analysis (Figure 3). The thresholds for interpreting water temperature were based on the criteria established by NMFS (1997) and additional criteria that were agreed upon by state agencies under the North Coast Watershed Assessment Program (NCWAP).

Based on these thresholds, Figure 3 identifies several areas that are potentially of concern, including:

- North Fork of the Noyo,
- South Fork of the Noyo (including Parlin Creek),
- North Fork of the Big River (including Chamberlain and James Creek), and
- South Fork of the Big River.

In addition, an emphasis was placed on those watersheds that either deliver water to JDSF (i.e., are up-stream) or are considered receiving waters (i.e., are downstream) from JDSF. Neither the Upper Noyo nor the South Fork of the Big River drain directly to JDSF, and as such, are discussed in less detail. The Mendocino Redwood Company (MRC) watershed analysis reports for the Noyo and Big River watersheds provide a thorough discussion of water temperature for these areas, although limited to that specific ownership. A summary of information from these reports is presented to provide a more comprehensive assessment of water temperature throughout the Noyo and Big River basins.

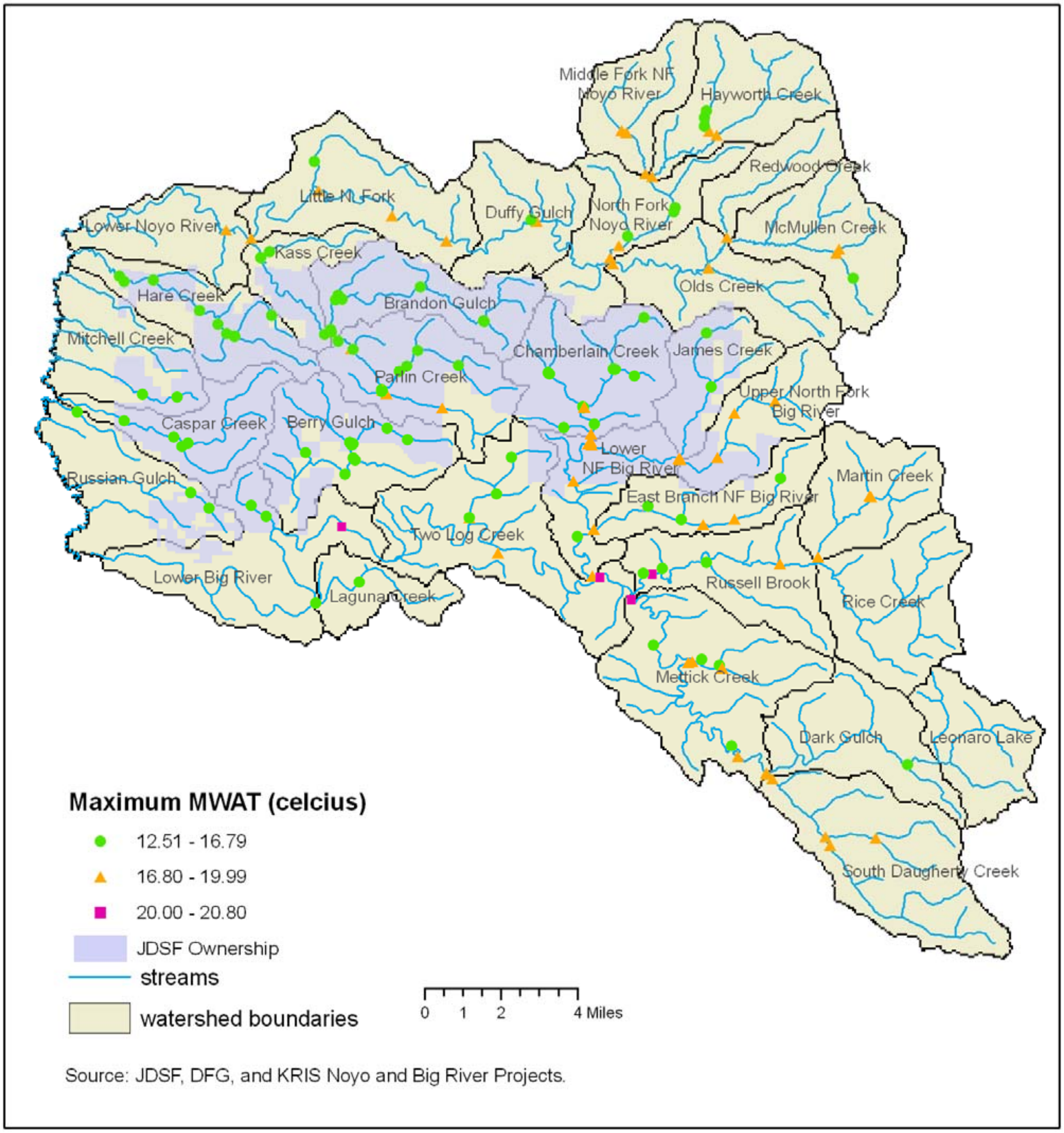

Figure 3. Distribution of Stream Temperatures across the Noyo and Big Rivers Based on the Maximum MWAT Values from 1994-2004.

Noyo River Water Temperature

Water temperatures across the Noyo River are generally desirable and below MWAT thresholds. However, water temperatures increase dramatically in the interior watersheds with the diminishing coastal influence. The warmest stream temperatures are recorded in the headwaters of the North Fork of the Noyo, where summer air temperatures can regularly exceed 100 °F.

A. Upper and Middle Noyo (outside JDSF)

The Upper Noyo consists of the headwaters of the Noyo (27 mi^2) and the North Fork of the Noyo River (25 mi^2). The upper end of the basin is directly west of the city of Willits. The upper mainstem of the Noyo drains a number of tributaries including: Olds Creek, Redwood Creek, McMullen Creek, NF Noyo River, Middle Fork of the NF Noyo River, and Hayworth Creek.

Stream temperature and canopy cover data were collected as part of the Noyo River Watershed Analysis across the MRC ownership in the Upper Noyo. Stream temperature was monitored in the Upper Noyo by Louisiana-Pacific Corp. from 1991 to1997 and MRC in 1999. MRC (2000) reported MWAT values for just 1996 and 1999. Stream temperatures were monitored during the summer months when the water temperatures are highest. Many of the monitoring stations recorded MWAT values that exceed the 16.8°C threshold (Welsh et al. 2001; NMFS and USFWS 1997). In addition, many stations recorded maximum stream temperatures that exceed 20°C. The highest stream temperatures were recorded on Hayworth Creek and along the mainstem of the Upper Noyo. It is presumed that these temperature spikes are associated with extremely warm weather conditions and are not sustained for long periods of time.

Stream temperature in the middle and lower portions of the mainstem Noyo are potentially of concern, although, there is little historic water temperature data available for comparison. Monitoring locations have consistently reported MWAT values that exceed the target threshold of 16.8 °C. Much cooler stream temperatures are reported for tributaries to the Noyo, with MWAT values ranging from 13.2 to 16.3°C (Table 3). Water temperatures for these tributaries have remained below the target threshold despite a history of intensive land management across each of these watersheds.

Table 3. Water Temperature (MWAT) for Tributaries to the Noyo River.

Stream Name	**Percent Harvested** 1986-2004	**Annual Instream Water Temperature (MWAT) (°C) (Target Temperature is ≤ 16.8° C**									
		1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
Little North Fork Noyo	80%	13.7	15.1	14.1	15.6	14.1	14.3	13.8	13.9	14.1	14.6
Duffy Gulch	83%				15.4	15.1	14.9	14.8	14.6		14.8
Kass Creek	63%	13.2	14.5	16.3	13.8	13.8	13.6	13.4	13.6	13.6	14.1

B. Water Temperature Data for the South Fork Noyo River (inside JDSF)

The South Fork of the Noyo River (SFNR) is a major tributary to the Noyo River. The SFNR catchment area at the confluence with the Noyo River drains a 27.32 mi^2 area, which is approximately 35% of the entire Noyo River watershed (113 mi^2). The vast majority of SFNR is owned and managed by JDSF. As such, JDSF management activities contribute to the overall water quality conditions in the lower Noyo, below its confluence with SFNR. The SFNR basin is characterized by steep mountainous terrain with confined valleys. The extreme headwaters of the SFNR have more moderate terrain.

The mainstem of the South Fork Noyo flows for approximately 7 miles through JDSF. Stream temperatures are characterized by fluctuations in maximum MWAT values as the river flows from the upstream boundary to the downstream boundary of JDSF (Figure 4). However, data recorded near the downstream boundary of JDSF has shown a noticeable decline for the last three years of record (site 1, Figure 4). For the most recent date (2000), the MWAT value for site number 1 was 16.2 °C. This is contrasted with much warmer readings on the mainstem of the Noyo above the confluence with the South Fork Noyo. Stream temperature data recorded on the middle Noyo (near Grove) have consistently recorded MWAT values at or near 18.6 °C from 1998 to 2003 (figure 1). Below the confluence with the SF Noyo, the water temperatures decline by about 1 °C (site 13, figure 4). Stream temperature data collected at the USGS gaging station along the mainstem of the lower Noyo has recorded an average MWAT value of 17.5 °C from 1998-2003. As such, the South Fork Noyo appears to have a moderate cooling effect on water temperatures in the lower Noyo depending upon the relative flow of the two streams.

Stream temperatures reported by Valentine (1996) provide a baseline for stream temperature along the South Fork Noyo River. The maximum single measurement (not MWAT) water temperatures identified at two monitoring locations were 19.4º C. All stations were below 18º C more than 85% of the time. Among the tributaries to the South Fork Noyo, Parlin Creek recorded the warmest temperatures. Data loggers along the South Fork Noyo, above and below the confluence (Figure 4, site 6 and 8), showed a modest increase in stream temperatures just below Parlin Creek. The degree to which stream temperatures along the South Fork Noyo are elevated by Parlin Creek were not considered significant by Valentine (1996), but were indicative of warming temperatures in lower reaches of Parlin Creek. Temperatures were shown to increase in the downstream direction along Parlin Creek. Valentine (1996) found that conditions did not represent a serious cause for concern with regard to coho salmon.

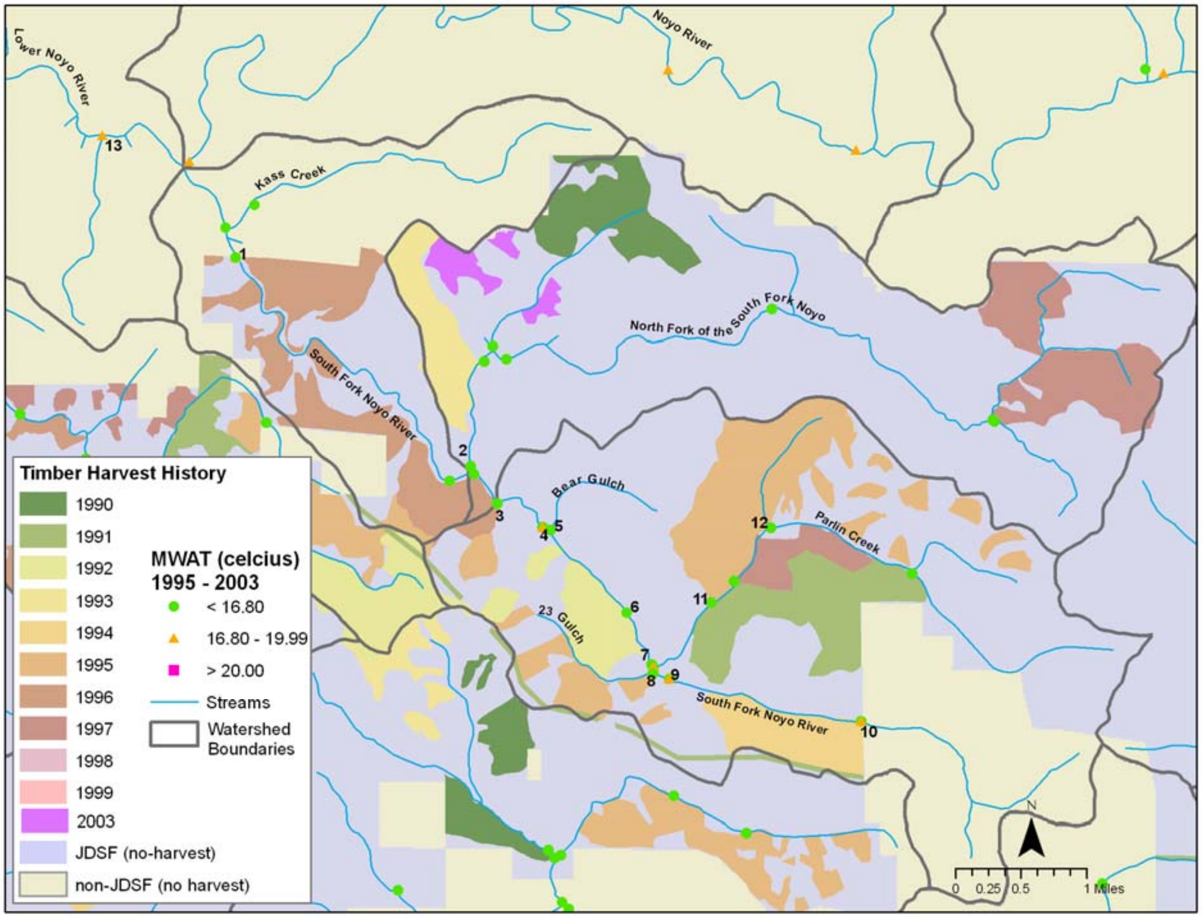

Figure 4. Distribution of Stream Temperatures along the South Fork Noyo River and Parlin Creek. Note: Timber Harvest boundaries ***do not*** reflect harvest restrictions in the WLPZ. There were no timber harvests for 2000–2002.

Stream temperature data following the 1996 study were analyzed to evaluate any changes from previously identified conditions. Treating 1996 as a baseline, data were analyzed post-1996 to determine if there are any trends in water temperature. Stream temperatures remain somewhat higher along the mainstem of the South Fork Noyo, about 0.5^{o} C, as water flows past Parlin Creek, but the trend is flat (Figure 5). This suggests that stream temperatures have been more or less stable since 1996. The area where Parlin Fork meets the South Fork contains a large opening associated with an historic homestead, logging camp, and current conservation camp. The riparian forest zone in this vicinity is relatively narrow. Recent timber harvests in both Parlin Creek and throughout the South Fork of the Noyo since 1996 do not appear to be influencing stream temperature.

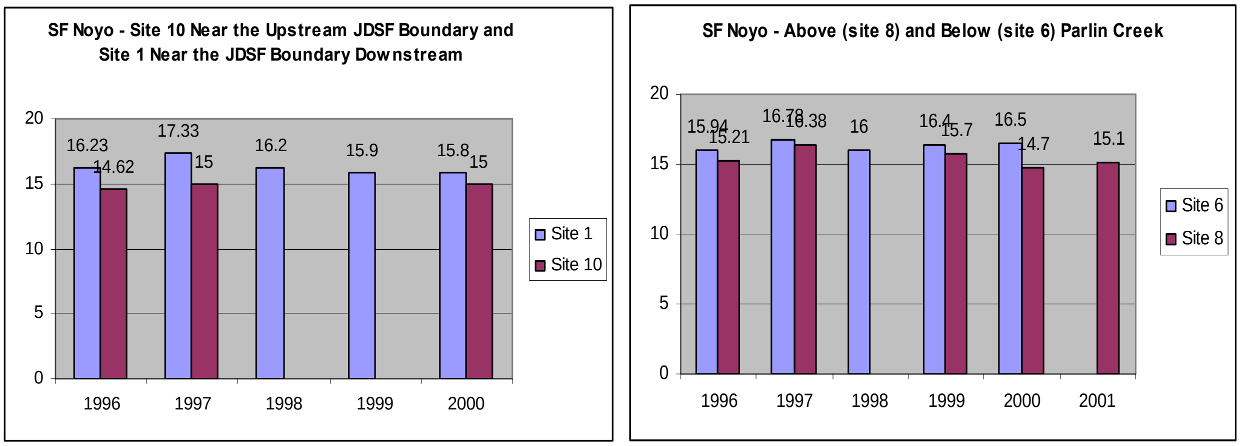

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Figure 5. Trends in MWAT Stream Temperatures (°C) along the South Fork Noyo River. Figure 5A provides a comparison in stream temperature from the upstream boundary of JDSF and the downstream boundary where water flows out of JDSF. Figure 5B provides a comparison of stream temperatures recorded directly above and below Parlin Creek. The water temperature is moderately warmer below Parlin Creek, but there is no dramatic increase or decrease over time.

Big River Water Temperature

The Big River watershed (181 mi^2) is larger than the Noyo, draining to the Pacific Ocean at the town of Mendocino. Most of basin is remote with few towns or incorporated areas. The topography varies from relatively flat marine terraces and estuaries to extremely rugged mountainous terrain. Land use within the watershed has been dominated by timber harvesting, with a substantial area dedicated to range management in the upper reaches. JDSF predominately influences water temperature along the North Fork of the Big River, and to a lesser extent, along the Little North Fork. Water temperature data along the mainstem of Big River consistently exceeds the 16.8°C MWAT threshold (Figure 3). The Big River is listed as temperature impaired per Section 303(d) of the federal Clean Water Act. Thus, management practices that have the potential to elevate stream temperatures are of concern. Water temperature data were assessed by the NCRWQCB staff under the NCWAP watershed assessment program and a summary of the data is provided in Attachment B. However, a more general discussion of water temperature issues is presented here for completeness of known water temperature issues.

A. South Fork of the Big River

The Mendocino Redwoods Company (MRC) has substantial ownership in the South Fork of the Big River. With ownership concentrated in Daugherty Creek, Mettick Creek and Russell Brook. MRC (2003) conducted a watershed analysis on their lands in the Big River basin, including an assessment of stream temperature and canopy cover. The temperature data for most sites were higher than the 16.8°C MWAT threshold for the North Fork of the Big River, with MWATs ranging from 17.4 to 19.7°C, and streamside canopy cover mostly moderate (40% – 70%). Conditions reported on the South Fork of Big River are similar. MWATs ranged from 18 to 18.4°C on the mainstem, with much cooler water recorded along tributaries (12.9 to 15.1°C).

B. North Fork of the Big River

Some of the warmest stream temperatures on JDSF have been recorded along the lower reaches of Chamberlain and James Creek (Figure 6). Chamberlain and James Creek are the eastern most watersheds that are predominately managed by JDSF. As interior watersheds, they can be influenced by very warm air temperatures throughout the summer months. Both watersheds have a history of intensive land management, but have had very little (none on JDSF lands) timber harvesting over the last 20 years. The maximum value for MWAT ranged from 13.8 to 18.9 °C, based on water temperature data collected from 1996 through 2003.

Stream temperatures are very similar at the mouth of James and Chamberlain Creeks. Chamberlain Creek is a larger watershed (7,868 acres) than James Creek (4,459 acres), but both have a similar north-south orientation. Both creeks exhibit a distinct increase in stream temperatures in the downstream direction. Based upon recorded MWAT values, stream temperatures increased by 2.5 °C in the downstream direction on Chamberlain and 3.5°C on James Creek (Figure 7B). Unlike the South Fork Noyo, there has been no timber harvesting in Chamberlain Creek since 1985, and only two recent harvest units in James Creek off of JDSF land. As such, canopy conditions are likely to have improved as a result of canopy development along both channels, where relatively young forest has re-grown to replace the old forest that existed prior to the 1940s and 1950s.

Stream temperature data have been collected at four locations along the North Fork of Big River (Figure 6). Stream temperature appears to be much higher upstream of the JDSF boundary, cooling as it passes through JDSF, and then increasing below the JDSF boundary (NCWAP, 2004, Attachment B). Stream temperature data loggers have recorded higher temperatures at the station above the confluence of James Creek than at downstream locations within JDSF. Stream temperatures do not appear to increase as water flows past the entrances of James and Chamberlain Creeks. Water temperatures recorded on the mainstem of the North Fork of the Big River are consistently higher than water temperatures recorded along the lower reaches of James and Chamberlain Creeks (Figure 7B). The computed MWAT recorded on the North Fork of the Big River upstream of Chamberlain is a full degree (Celsius) higher than the MWAT recorded from the station on Chamberlain Creek just above its confluence with Big River. As such, the conditions within JDSF appear to have a moderating temperature effect upon water flowing into the state forest. As canopy continues to develop adjacent to these stream reaches in the future, the cooling trend is likely to continue and to improve.

The lower portions of the East Branch of the North Fork of the Big River were included in a recent watershed assessment conducted by Mendocino Redwoods Company (MRC, 2003). Streamside canopy cover was mostly high (> 90%) and MWAT values range from 16.3 to 18.4°C along the mainstem. Temperature data on tributaries (Class II watercourses) were limited to one year of data, but all sites recorded MWAT values below 15°C.

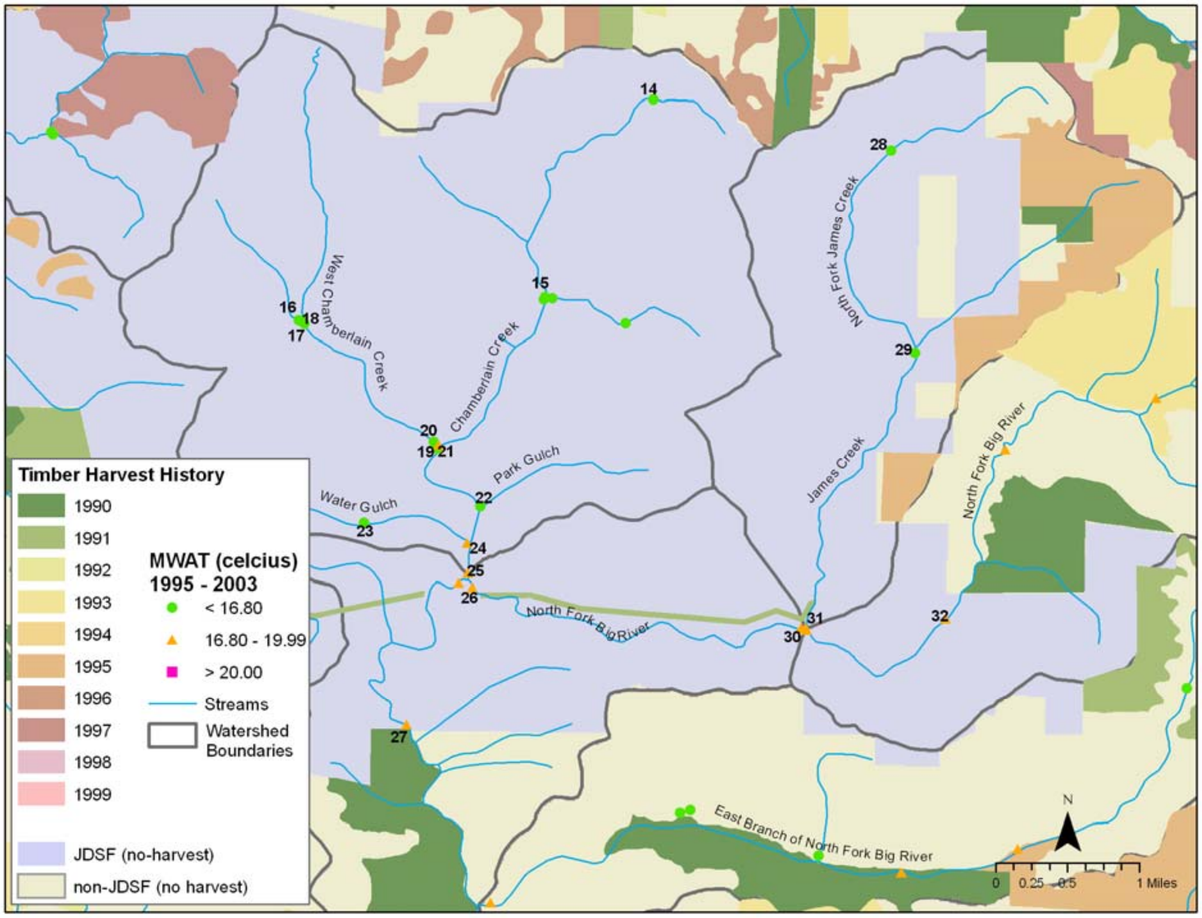
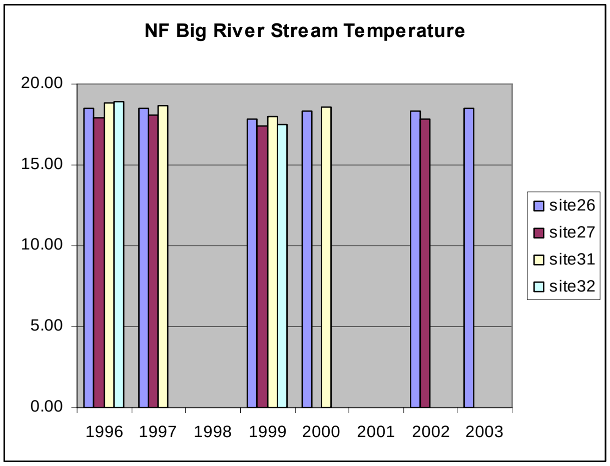


Figure 6. Distribution of Stream Temperatures along the North Fork Big River, Chamberlain and James Creeks. Note: Timber Harvest boundaries ***do not*** reflect harvest restrictions in the WLPZ.



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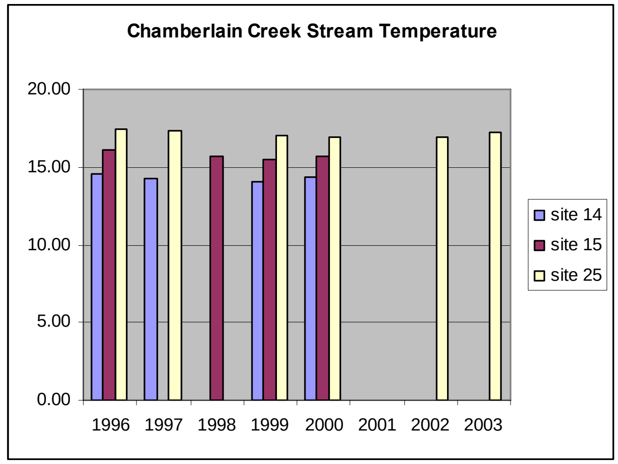

B

Figure 7. Stream Temperature (MWAT °C) for North Fork Big River and Chamberlain Creek. Figure 7A. MWAT stream temperatures along the North Fork of the Big River are consistently above the target threshold of 16.8 °C. However, there is not a noticeable increase of stream temperature from the upstream boundary of JDSF (site 32) to the downstream boundary of JDSF (site 27). Figure 7B. From the headwaters to the confluence, MWAT stream temperatures increase in the downstream direction along Chamberlain Creek by as much as 3 °C. This trend is fairly consistent over time, with some indication of a decrease in stream temperature at the furthest downstream station (site 25) recorded in the last 4 years of data collection.

Coastal Watersheds

Management practices on JDSF lands also influence a number of small coastal watersheds that drain directly to the Pacific Ocean. These watersheds include Russian Gulch, Caspar Creek, Jughandle Creek, Mitchell Creek, and Hare Creek. In general, the stream temperatures appear to be in a range that is supportive for salmonids. None of the temperature data for these watersheds has exceeded the 16.8 °C MWAT threshold.

Nearly all of the early temperatures monitoring efforts were in the Caspar Creek watershed. Cafferata (1990) reported pre-management water temperatures in the North Fork and South Fork Caspar Creeks. Most observed summer maximum stream temperatures in 1965 were slightly below 16°C (60°F) with absolute maximums reaching 17°C (62.6°F) at the weirs. In 1988, small uncut tributary basins had maximum temperatures of about 13°C (56°F) with average daily highs about 12°C (54°F). Cafferata (1990) reported approximately a 13% reduction in shading resulting from timber harvesting along a Class II watercourse channel in the North Fork Caspar Creek (note that shading and canopy, while related, are two different measurements; see Berbach et al. 1999). Following clearcut logging of approximately 50% of the North Fork of the Caspar Creek watershed with buffer strips prescribed by the modern Forest

Practice Rules, Nakamoto (1998) concluded that the increase in water temperature was small and the range of temperatures observed within the North Fork was within the tolerable range for coho salmon and steelhead.

Stream Canopy Cover

Streamside canopy densities are relatively high throughout JDSF. Stillwater Sciences estimated canopy cover for streams in or adjacent to JDSF in 1996 (Table 4). This survey emphasized fish bearing streams (Class I). In addition, stream surveys have been conducted by CDFG. Of the 35 stream surveys conducted by CDFG between 1995 and 1997, 25 streams had canopy densities exceeding 90%, 6 streams exceeded 80% and 4 streams were between 60 and 79% (see Map Figure F in Map Figures section).

Table 4. Summary of Streamside Canopy Cover Data for Streams in or adjacent to JDSF. Based on 1996 vegetation conditions, the data are summarized by Planning Watersheds.

	SHADE CATAGORIES (UNITS = MILES)						
PWSNAME	**< 40%**		**40 - 70%**		**70 - 100%**		**Total**
	miles	**percent**	**miles**	**percent**	**miles**	**percent**	**miles**
Berry Gulch	0.87	3.0		0.0	27.73	97.0	28.60
Brandon Gulch		0.0		0.0	24.74	100.0	24.74
Caspar Creek	0.33	1.8		0.0	17.86	98.2	18.20
Chamberlain Creek	0.34	1.1	1.17	3.7	30.22	95.2	31.73
East Branch North Fork Big River	2.17	12.4	0.33	1.9	15.02	85.7	17.52
Hare Creek		0.0		0.0	23.75	100.0	23.75
James Creek		0.0	1.22	7.7	14.55	92.3	15.77
Kass Creek		0.0	0.45	3.2	13.36	96.8	13.81
Laguna Creek		0.0		0.0	0.00	100.0	0.00
Lower North Fork Big River	3.43	17.3	1.25	6.3	15.10	76.3	19.78
Mitchell Creek		0.0		0.0	15.62	100.0	15.62
Mouth of Big River	5.44	15.1	6.04	16.8	24.53	68.1	36.01
Mouth of Noyo River		0.0		0.0	0.01	100.0	0.01
Parlin Creek	1.60	5.3	0.60	2.0	28.06	92.7	30.26
Russian Gulch		0.0		0.0	14.19	100.0	14.19
Two Log Creek	12.67	29.0		0.0	31.01	71.0	43.67
Upper North Fork Big River		0.0		0.0	17.93	100.0	17.93
Grand Total	26.84		11.06		313.70		351.60

Outside JDSF, canopy cover data has been collected as part of the Department of Fish and Game (DFG) stream surveys that were conducted between 1995 and 2003. The information relating streamside canopy cover and forest composition is presented in Attachment C. In summary, the data show that most of the streams that were surveyed meet or exceed the 85% canopy cover target. Stream reaches that do not can be found along the mainstem of the Big River, the mainstem of the Noyo, North Fork of the Big

River, South Fork of the Big River, and some of the major tributaries (i.e., Daughtery Cr., Mettick Cr., and James Cr).

Additional information on canopy cover is contained in watershed assessments that have been conducted by private landowners. Streamside canopy cover data were collected by MRC for their lands in the Noyo River watershed in 1998. Canopy cover were grouped into three classes: high (>70%), moderate (40–70%) and low (0–40%). The canopy closure assessment showed a majority of Class I streams with a high streamside shade classification (58% of total Class I watercourses). However, a significant percentage of the Noyo watershed assessment unit Class I streams have a moderate streamside shade classification (28% of Class I watercourses) and low streamside shade classification (14% of Class I watercourses). Streamside canopy cover data also were collected by MRC for their lands on the Big River to support a watershed assessment conducted in 2000. Canopy cover ranged from 40%-100% across MRC lands in the Big River. In general, canopy cover appears lowest among the mainstem of the larger river channels and is summarized as (MRC 2003):

> Canopy closure over watercourses in the Big River WAU [watershed assessment unit] ranges from poor to good. Big River, North Fork Big River and South Fork Big River have less than ideal canopy cover values but this is to be expected from larger river channels. East Branch North Fork Big River and Two Log Creek are two areas that have good canopy cover. Daugherty Creek is an area which has low canopy cover.

Discussion

In addition to a number of other factors, stream temperatures are affected by varying amounts of canopy cover that are the result of differing intensities of harvest and the natural conditions encountered throughout a watershed. The potential impact of timber harvesting on water temperatures can result from a single action, or the cumulative impact of multiple harvests. The recovery from this impact (i.e., return to a temperature regime associated with pre-harvest conditions) should consider both the upstream and downstream canopy conditions and the time required for full canopy cover to be re-established. Studies have shown that stream temperatures will return to equilibrium conditions within 10 km downstream of the harvest area (Bartholow 2000). Studies in Oregon have shown that canopy cover and water temperatures had fully recovered within 15 years following intensive harvesting within three experimental watersheds, but this is dependent upon the localized canopy and channel conditions, and the type of harvesting conducted. The North Fork Caspar Creek study (Nakamoto 1998) discussed above showed that clearcutting 50 percent of the watershed using buffer strips prescribed by contemporary Forest Practice Rules led to a small increase in water temperature; temperatures remained within the range considered suitable for coho and steelhead.

The previous discussion on the effects of timber harvesting on stream temperatures provides an assessment of current conditions and direct impacts associated with canopy cover. While not as well understood, there are other physical changes besides canopy cover that can have a cumulative influence on stream temperatures. The development of a stream temperature model by Bartholow (2000) provides insight into a range of secondary impacts that may result from timber harvesting and the degree to which they influence stream temperatures. While stream shade was an important factor, explaining 40% of the increase in stream temperature, it was not the only factor. Stream width was an important secondary factor

The model identified effects directly related to stream temperatures that are associated with: meteorology, hydrology, and stream geometry (Figure 8). Changes in meteorology refer to the micro-climate dynamics within a riparian zone. On JDSF, recent studies by Hughes et al (2004) focused on changes in riparian micro-climate as a result of timber harvest. Results have shown distinctive temperature gradients that increase with distance from the stream channel. Hydrologic changes are addressed in a separate section of the EIR, but in summary, findings from Caspar Creek suggest a recovery time of approximately 11 years for changes in peak flow. Changes in stream geometry, channel width and depth, are not well documented across the assessment area. However, historic land management practices are very likely to have altered stream geometry across large portions of the assessment area. Recovery of a more natural stream geometry from these substantial historic impacts will take a long time.

Summary

Water temperatures vary both spatially and temporally across the JDSF EIR assessment area. In general, stream temperatures are highest in some of the larger tributaries towards the interior (i.e., eastern) portions, and along portions of the mainstem Noyo River, the Big River and the North and South Forks of the Big River. Achieving targets for canopy cover will require a period of time sufficient to increase both tree height and canopy density. In addition, stream temperatures in a watershed tend to increase in the downstream direction and increase with increasing watershed area (Figure 1). Water temperature data indicate that stream temperatures along the middle and upper mainstem of the Noyo River remain warm and are consistently warmer than water temperatures measured along the lower reaches of the South Fork Noyo downstream of JDSF. This is undoubtedly due to the fact that the channels are wider, have been subjected to substantial canopy reductions in the past, and trees growing along the margins of the stream are incapable of fully shading the full channel width.

To prevent any future impacts to water temperature from the proposed management plan JDSF will meet or exceed all watercourse protection measures as stated in the FPRs. In addition, JDSF is committed to maintaining a network of monitoring stations that can be used to document trends in water temperature and identify potential impacts on water temperature from forest management. Currently, most streams within JDSF consistently record water temperature that is below the MWAT threshold of 16.8 C. However, Parlin Creek, Chamberlain Creek and James Creek have all recorded MWAT values that exceed this threshold and are areas of potential concern. These areas should be priorities for continued monitoring and canopy development.

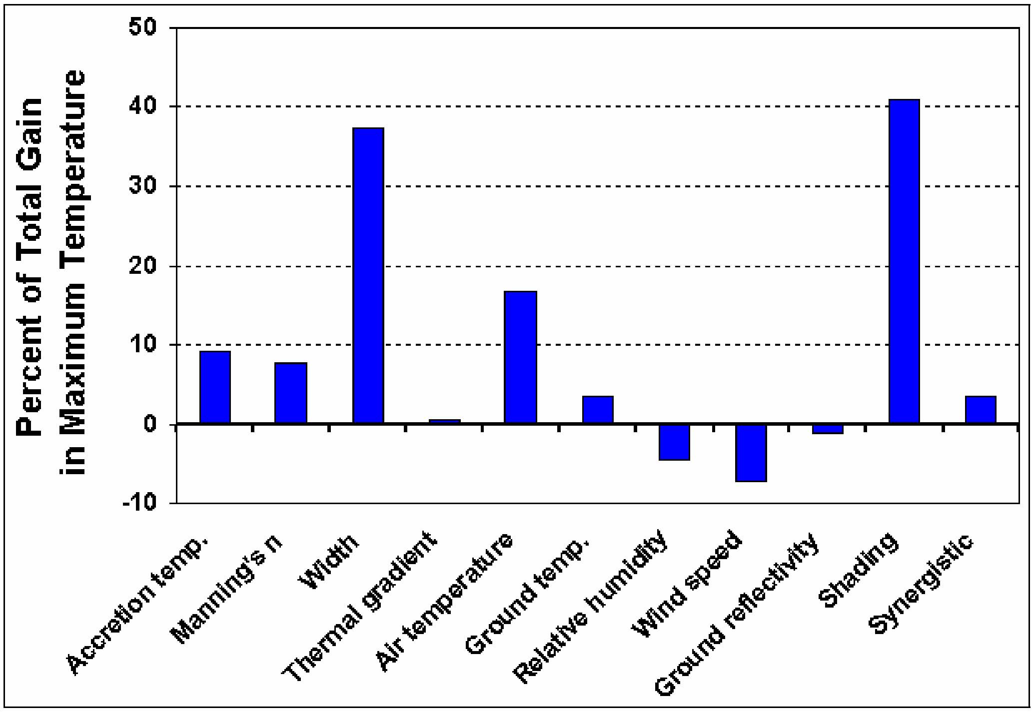

Figure 8. Stream Temperature Model Results. Model shows environmental conditions that are affected by timber harvesting and the relative magnitude of their influence on stream temperatures. Note that values above zero indicate increasing stream temperatures, while values below zero indicate decreasing temperatures (Bartholow, 2000).

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Attachment A

Stream Temperature Data Summary

PLANNING WATERSHEDS	Site	Avg	Max	Min	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
BIG RIVER HEADWATERS																	
Martin Creek	FSP_5219	18.4	18.6	18.3	0.0	0.0	0.0	0.0	0.0	0.0	18.6	18.3	0.0	0.0	0.0	0.0	0.0
	FSP_5235	16.0	17.3	14.7	0.0	0.0	0.0	0.0	0.0	0.0	17.3	14.7	0.0	0.0	0.0	0.0	0.0
	FSP_5240	17.4	17.8	17.0	0.0	0.0	0.0	0.0	0.0	0.0	17.0	17.8	0.0	0.0	0.0	0.0	0.0
Russel Brook	MRC_T74-01	19.5	20.1	19.0	0.0	20.1	19.0	19.0	0.0	0.0	0.0	0.0	0.0	19.3	19.9	19.4	0.0
	MRC_T74-02	15.8	16.6	14.9	0.0	0.0	0.0	15.2	16.6	0.0	0.0	0.0	0.0	16.0	14.9	15.7	16.6
	MRC_T74-03	18.4	19.0	16.0	0.0	0.0	0.0	18.8	16.0	0.0	0.0	0.0	18.8	0.0	18.8	19.0	18.9
	MRC_T74-20	14.2	14.2	14.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	14.2	0.0	0.0
	MRC_T74-21	14.7	14.7	14.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	14.7	0.0	0.0
NORTH FORK BIG RIVER																	
Upper North Fork Big River	JDSF_3201	18.2	18.9	17.5	0.0	0.0	0.0	0.0	0.0	18.9	0.0	0.0	17.5	0.0	0.0	0.0	0.0
	JDSF_3202	18.5	18.9	18.0	0.0	0.0	0.0	0.0	0.0	18.9	18.7	0.0	18.0	18.6	0.0	0.0	0.0
	JDSF_3213	17.1	17.5	16.8	0.0	0.0	0.0	0.0	0.0	16.8	0.0	0.0	17.0	0.0	0.0	17.0	17.5
	FSP_5220	18.1	18.6	17.5	0.0	0.0	0.0	0.0	0.0	0.0	18.6	17.5	0.0	0.0	0.0	0.0	0.0
	FSP_5238	17.7	18.1	17.3	0.0	0.0	0.0	0.0	0.0	0.0	18.1	17.3	0.0	0.0	0.0	0.0	0.0
James Creek	JDSF_3211	15.1	15.8	14.8	0.0	0.0	0.0	0.0	0.0	15.1	15.8	0.0	14.8	14.8	0.0	0.0	0.0
	JDSF_3212	16.3	16.8	15.9	0.0	0.0	0.0	0.0	0.0	16.8	0.0	0.0	15.9	16.2	0.0	0.0	0.0

PLANNING WATERSHEDS	Site	Avg	Max	Min	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
Chamberlain Creek	JDSF_3221	14.3	14.5	14.1	0.0	0.0	0.0	0.0	0.0	14.5	14.2	0.0	14.1	14.4	0.0	0.0	0.0
	JDSF_3222	15.8	16.1	15.5	0.0	0.0	0.0	0.0	0.0	16.1	0.0	0.0	15.5	15.7	0.0	0.0	0.0
	JDSF_3223	16.3	16.3	16.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	16.3	16.2	0.0	0.0	0.0
	JDSF_3224	17.1	17.5	16.9	0.0	0.0	0.0	0.0	0.0	17.5	17.3	0.0	17.0	16.9	0.0	16.9	17.3
	JDSF_3231	15.0	15.2	14.7	0.0	0.0	0.0	0.0	0.0	15.2	15.0	0.0	15.0	14.7	0.0	0.0	0.0
	JDSF_X14	14.1	14.6	13.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	13.8	13.8	14.6
	JDSF_X15	15.2	15.7	14.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	15.0	14.9	15.7
	JDSF_X16	14.5	14.9	14.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	14.9	14.7	14.0	0.0	0.0
	JDSF_X17	15.6	16.2	15.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	15.3	15.4	16.2
	JDSF_X18	16.9	16.9	16.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	16.9
	JDSF_X19	17.6	17.6	17.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	17.6
	JDSF_X20	15.3	15.3	15.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	15.3
	JDSF_X21	15.7	15.7	15.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	15.7	0.0	0.0	0.0	0.0	0.0
	JDSF_X22	15.7	15.9	15.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	15.9	15.4	0.0	0.0	0.0	0.0
	FSP_556	16.0	16.0	16.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	16.0	0.0	0.0	0.0	0.0	0.0
East Branch North Fork Big	MRC_T75-01	17.4	18.4	16.4	0.0	0.0	18.4	0.0	18.1	0.0	17.9	0.0	17.1	17.1	16.4	16.6	17.4
	MRC_T75-03	17.2	17.9	16.3	0.0	0.0	0.0	0.0	0.0	0.0	17.9	0.0	0.0	0.0	16.3	17.0	17.7
	MRC_T75-20	12.1	12.1	12.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	12.1	0.0	0.0
	MRC_T75-22	13.6	13.6	13.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	13.6	0.0	0.0
	MRC_T75-05	14.4	15.3	13.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	13.5	15.3
	FSP_5213	17.5	18.1	16.9	0.0	0.0	0.0	0.0	0.0	0.0	18.1	16.9	0.0	0.0	0.0	0.0	0.0
	FSP_5234	15.7	15.8	15.6	0.0	0.0	0.0	0.0	0.0	0.0	15.6	15.8	0.0	0.0	0.0	0.0	0.0

PLANNING WATERSHEDS	Site	Avg	Max	Min	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
Lower North Fork Big River	MRC_T75-04	18.5	19.2	17.4	0.0	0.0	19.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	17.4	19.0
	MRC_T75-23	13.2	13.2	13.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	13.2	0.0	0.0
	JDSF_3203	18.5	18.5	18.5	0.0	0.0	0.0	0.0	0.0	18.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	JDSF_3204	18.3	18.5	17.8	0.0	0.0	0.0	0.0	0.0	18.5	18.5	0.0	17.8	18.3	0.0	18.4	18.5
	JDSF_3205	17.9	17.9	17.9	0.0	0.0	0.0	0.0	0.0	17.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	JDSF_3206	17.8	18.1	17.4	0.0	0.0	0.0	0.0	0.0	18.0	18.1	0.0	17.4	17.8	0.0	0.0	0.0
SOUTH FORK BIG RIVER																	
Dark Gulch	FSP_552	15.5	15.7	15.3	0.0	0.0	0.0	0.0	0.0	15.5	15.3	15.7	0.0	0.0	0.0	0.0	0.0
South Daugherty Creek	MCWA_154	17.8	18.1	17.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	18.1	0.0	17.4	18.0	0.0
	MRC_T79-04	18.7	19.3	18.2	0.0	0.0	0.0	18.7	19.3	0.0	18.4	0.0	18.2	19.0	18.4	18.5	19.1
	MRC_T79-05	18.3	18.7	17.8	0.0	0.0	0.0	0.0	0.0	0.0	18.7	0.0	0.0	0.0	0.0	17.8	18.3
	MRC_T79-09	17.8	18.8	16.5	0.0	0.0	0.0	0.0	0.0	0.0	18.2	0.0	0.0	0.0	16.5	17.7	18.8
	MRC_T79-13	17.1	17.4	16.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	16.7	17.4
Mettick Creek	MCWA_155	18.1	18.3	18.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	18.3	0.0	18.0	0.0	0.0
	MRC_T79-01	20.1	20.6	19.5	0.0	0.0	0.0	0.0	0.0	20.6	20.5	0.0	20.0	20.4	19.5	19.7	20.3
	MRC_T79-02	18.5	18.7	18.2	0.0	0.0	0.0	0.0	0.0	18.7	18.4	0.0	18.7	0.0	0.0	18.2	18.5
	MRC_T79-08	15.4	16.6	14.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	15.1	0.0	14.5	16.6
	MRC_T79-10	18.2	18.3	18.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	18.0	18.3

PLANNING WATERSHEDS	Site	Avg	Max	Min	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
	MRC_T79-11	19.4	19.7	19.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	19.1	19.7
	MRC_T79-12	19.2	19.9	18.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	18.4	19.9
	MRC_T79-20	14.0	14.0	14.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	14.0	0.0	0.0
	MRC_T79-21	13.8	13.8	13.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	13.8	0.0	0.0
	MRC_T79-22	12.9	12.9	12.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	12.9	0.0	0.0
LOWER BIG RIVER																	
Laguna Creek	CTM_BIG12	16.1	16.1	16.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	16.1	0.0	0.0	0.0	0.0	0.0
	CTM_BIG14	16.1	16.1	16.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	16.1	0.0	0.0	0.0	0.0	0.0
Berry Gulch	CTM_BIG10	14.9	15.6	14.4	0.0	0.0	0.0	14.6	15.6	15.0	0.0	14.9	15.0	14.8	14.4	0.0	15.0
	CTM_BIG8	15.5	16.2	14.6	0.0	0.0	0.0	15.2	16.2	15.8	0.0	15.6	15.6	15.5	14.6	15.4	15.5
	CTM_BIG9	14.7	15.6	13.9	0.0	0.0	0.0	0.0	15.6	0.0	0.0	15.0	14.9	14.4	13.9	0.0	14.7
	JDSF_3301	14.1	14.6	13.6	0.0	0.0	0.0	0.0	0.0	13.6	14.6	0.0	14.3	14.0	0.0	0.0	0.0
	JDSF_3302	15.2	15.8	15.0	0.0	0.0	0.0	0.0	0.0	15.3	15.8	0.0	15.0	15.0	0.0	15.2	15.1
	JDSF_3311	14.9	15.0	14.8	0.0	0.0	0.0	0.0	0.0	14.9	0.0	14.8	15.0	0.0	0.0	0.0	0.0
	JDSF_3321	13.9	14.1	13.8	0.0	0.0	0.0	0.0	0.0	13.8	0.0	0.0	0.0	0.0	14.1	0.0	0.0
	JDSF_X08	14.0	14.9	13.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	13.5	13.4	14.9	14.2	0.0
	JDSF_X10	14.2	14.2	14.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	14.2	0.0	0.0
Mouth of Big River	CTM_BIG11	19.3	20.8	15.6	0.0	0.0	0.0	0.0	0.0	15.6	0.0	20.8	20.4	20.2	0.0	0.0	0.0
	CTM_BIG15	20.4	20.4	20.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	20.4	20.4
	JDSF_3331	14.8	15.9	14.0	0.0	0.0	0.0	0.0	0.0	14.0	15.9	14.4	14.9	14.8	0.0	0.0	0.0
	JDSF_X05	14.2	14.5	13.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	14.2	13.8	14.5
Two Log Creek	CTM_BIG3	16.3	17.1	15.5	0.0	0.0	0.0	15.5	17.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

PLANNING WATERSHEDS	Site	Avg	Max	Min	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
	CTM_BIG1	20.5	20.9	19.9	0.0	0.0	0.0	20.8	20.9	20.7	0.0	20.6	20.3	20.7	19.9	20.1	20.5
	CTM_BIG13	20.6	20.9	20.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	20.9	20.7	0.0	20.2	20.6	20.6
	CTM_BIG4	15.7	17.1	14.2	0.0	0.0	0.0	15.5	17.1	0.0	0.0	16.4	15.3	15.6	14.2	15.3	16.0
	CTM_BIG5	14.3	14.9	13.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	13.7	14.9
	MRC_T76-01	19.8	20.6	19.3	0.0	0.0	19.7	19.3	0.0	0.0	0.0	0.0	19.4	0.0	0.0	0.0	20.6
	MRC_T76-02	15.4	15.8	14.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	15.8	14.8	15.3	15.5
	MRC_T76-20	13.4	13.4	13.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	13.4	0.0	0.0
NOYO HEADWATERS																	
Hayworth Creek	MRC_T70-03	18.2	19.8	16.8	19.1	19.8	18.9	18.3	18.1	18.2	0.0	0.0	16.8	17.8	17.2	17.1	18.6
	MRC_T70-05	17.3	17.9	16.7	0.0	0.0	0.0	17.5	17.6	17.9	0.0	0.0	16.8	17.2	17.2	16.7	17.8
	MRC_T70-06	17.9	18.9	17.1	0.0	0.0	0.0	0.0	0.0	18.9	18.2	0.0	17.1	17.5	17.4	17.9	18.4
	MRC_T70-23	13.5	13.5	13.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	13.5	0.0	0.0
	MRC_T70-24	13.8	13.8	13.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	13.8	0.0	0.0
	MRC_T70-25	13.5	13.5	13.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	13.5	0.0	0.0
McMullen Creek	CTM_NOY10	16.2	16.3	16.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	16.3	16.1	16.1	0.0	0.0	0.0
	MRC_T70-13	16.7	17.5	16.2	0.0	0.0	0.0	0.0	0.0	17.5	16.6	0.0	16.5	0.0	16.2	16.2	17.0
	MRC_T70-14	17.2	17.2	17.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	17.2	0.0	0.0	0.0
Middle Fork N. Fork Noyo	MRC_T70-07	17.3	18.4	16.3	17.9	18.0	17.3	18.4	0.0	17.4	0.0	0.0	16.5	16.8	16.3	0.0	0.0
	MRC_T70-08	15.9	17.1	13.9	0.0	0.0	0.0	15.6	16.3	16.7	0.0	0.0	13.9	15.9	15.9	15.6	17.1
	MRC_T70-10	15.8	16.8	15.2	0.0	0.0	0.0	0.0	16.1	0.0	0.0	0.0	15.7	16.0	15.2	15.2	16.8
North Fork Noyo	MRC_T70-01	17.8	18.5	17.1	0.0	18.5	17.8	17.1	17.7	18.0	0.0	0.0	17.3	17.3	17.5	18.1	18.4

PLANNING WATERSHEDS	Site	Avg	Max	Min	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
	MRC_T70-02	15.2	16.1	13.2	0.0	0.0	0.0	15.0	15.7	15.6	0.0	0.0	13.2	15.3	15.3	15.2	16.1
	MRC_T70-20	19.7	19.7	19.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	19.7	0.0	0.0
	MRC_T70-21	14.0	14.0	14.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	14.0	0.0	0.0
	MRC_T70-22	13.3	13.3	13.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	13.3	0.0	0.0
Olds Creek	MRC_T70-11	17.7	18.8	15.6	0.0	18.3	17.9	17.1	17.9	18.1	15.6	0.0	17.9	17.6	17.9	17.7	18.8
	MRC_T70-15	17.4	17.4	17.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	17.4
Redwood Creek	MRC_T70-12	17.0	18.1	15.8	0.0	0.0	0.0	16.4	17.4	17.7	0.0	0.0	16.6	17.3	15.8	16.7	18.1
MIDDLE NOYO																	
Duffy Gulch	CTM_NOY11	18.4	19.0	17.9	0.0	0.0	0.0	0.0	0.0	0.0	17.9	18.5	18.3	18.5	18.2	18.8	19.0
	CTM_NOY2	14.9	15.4	14.6	0.0	0.0	0.0	0.0	0.0	0.0	15.4	15.1	14.9	14.6	14.6	0.0	14.8
Little North Fork	CTM_NOY12	17.9	18.1	17.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	17.8	18.1
	CTM_NOY13	18.5	18.7	18.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	18.7	18.5	18.6	18.1	18.6	18.6
	CTM_NOY14	18.6	18.6	18.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	18.6	18.5	18.6	18.4	0.0	18.6
	CTM_NOY4	18.1	18.3	17.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	18.3	18.2	17.8	18.1	18.1
	CTM_NOY5	14.3	15.6	13.7	0.0	0.0	0.0	13.7	15.1	14.1	15.6	14.1	14.3	13.8	13.9	14.1	14.6
SOUTH FORK NOYO RIVER																	
Brandon Gulch	JDSF_2508	15.6	15.6	15.6	0.0	0.0	0.0	0.0	0.0	15.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	JDSF_2571	14.9	15.2	14.7	0.0	0.0	0.0	0.0	0.0	14.9	15.2	14.9	14.7	0.0	0.0	0.0	0.0
	JDSF_2572	15.4	15.7	15.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	15.3	15.4	15.2	15.3	15.2	15.7
	JDSF_2573	16.0	16.7	15.6	0.0	0.0	0.0	0.0	0.0	16.1	16.7	15.6	15.9	15.6	0.0	0.0	0.0
	JDSF_X06	14.6	15.1	14.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	14.8	14.5	14.3	14.4	15.1
	JDSF_X07	15.6	16.0	15.3	0.0	0.0	0.0	0.0	0.0	15.3	16.0	0.0	0.0	0.0	0.0	0.0	0.0

PLANNING WATERSHEDS	Site	Avg	Max	Min	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
	JDSF_X12	14.0	14.0	14.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	14.0	14.0	0.0
	JDSF_X13	13.8	14.5	13.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	13.3	13.5	14.5
Kass Creek	CTM_NOY6	15.8	15.9	15.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	15.9	15.7	15.8	0.0	0.0
	CTM_NOY7	14.0	16.3	13.2	0.0	0.0	0.0	13.2	14.5	0.0	16.3	13.8	13.6	13.5	13.6	13.6	14.1
	JDSF_2509	15.9	15.9	15.9	0.0	0.0	0.0	0.0	0.0	15.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Parlin Creek	JDSF_2501	15.8	17.3	14.6	0.0	0.0	0.0	0.0	0.0	16.2	17.3	16.2	15.9	15.8	0.0	0.0	0.0
	JDSF_2502	16.9	17.4	16.7	0.0	0.0	0.0	0.0	0.0	16.9	0.0	17.0	17.4	16.8	16.8	16.7	16.9
	JDSF_2503	15.4	16.4	14.7	0.0	0.0	0.0	0.0	0.0	15.2	16.4	0.0	15.7	14.7	15.1	0.0	0.0
	JDSF_2504	16.3	16.8	15.9	0.0	0.0	0.0	0.0	0.0	15.9	16.8	16.0	16.4	16.5	0.0	0.0	0.0
	JDSF_2506	16.3	17.3	16.0	0.0	0.0	0.0	0.0	0.0	16.0	17.3	16.1	16.5	16.3	16.1	16.1	16.3
	JDSF_2531	14.6	15.0	14.3	0.0	0.0	0.0	0.0	0.0	14.7	14.5	14.5	15.0	14.7	14.4	14.3	14.9
	JDSF_2532	15.4	16.0	15.1	0.0	0.0	0.0	0.0	0.0	15.1	15.6	15.2	15.5	15.1	15.1	15.7	16.0
	JDSF_2533	15.5	15.5	15.5	0.0	0.0	0.0	0.0	0.0	15.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	JDSF_2534	16.5	17.1	16.1	0.0	0.0	0.0	0.0	0.0	16.3	17.1	16.1	0.0	0.0	0.0	0.0	0.0
	JDSF_2551	14.6	15.4	14.0	0.0	0.0	0.0	0.0	0.0	14.0	15.4	14.2	0.0	15.0	0.0	14.2	14.7
	JDSF_2561	13.9	15.1	13.0	0.0	0.0	0.0	0.0	0.0	13.0	15.1	14.0	14.2	13.7	13.6	0.0	0.0
	JDSF_X09	14.7	15.5	14.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	14.7	15.5	14.0	0.0	0.0
	JDSF_X11	15.7	16.1	15.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	16.1	15.8	15.5	15.5	15.8
LOWER NOYO RIVER																	
Lower Noyo River	CTM_NOY9	17.4	18.1	16.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	18.1	17.6	16.6	17.4	17.2	17.8

PLANNING WATERSHEDS	Site	Avg	Max	Min	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
COASTAL																	
Caspar Creek	JDSF_3401	14.6	15.5	14.1	0.0	0.0	0.0	0.0	0.0	14.1	15.5	14.5	0.0	14.3	0.0	0.0	0.0
	JDSF_3402	15.0	15.0	15.0	0.0	0.0	0.0	0.0	0.0	15.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	JDSF_3411	14.6	15.8	13.9	0.0	0.0	0.0	0.0	0.0	13.9	15.8	14.2	0.0	0.0	0.0	0.0	0.0
	FSP_5801	14.2	14.2	14.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	14.2	0.0	0.0	0.0	0.0	0.0
Hare Creek	JDSF_2402	14.2	14.3	14.0	0.0	0.0	0.0	0.0	0.0	14.0	0.0	14.2	14.3	14.1	0.0	0.0	0.0
	JDSF_2403	14.8	15.7	13.9	0.0	0.0	0.0	0.0	0.0	13.9	15.7	0.0	0.0	0.0	0.0	0.0	0.0
	JDSF_2404	13.8	13.8	13.8	0.0	0.0	0.0	0.0	0.0	13.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	JDSF_2405	14.3	15.0	13.8	0.0	0.0	0.0	0.0	0.0	0.0	15.0	0.0	13.8	14.1	0.0	0.0	0.0
	JDSF_2411	13.7	14.4	13.1	0.0	0.0	0.0	0.0	0.0	13.1	14.4	13.4	13.6	13.8	0.0	0.0	0.0
	JDSF_2412	14.7	15.8	14.3	0.0	0.0	0.0	0.0	0.0	14.6	15.8	14.5	0.0	14.5	14.5	14.3	15.0
	JDSF_X01	14.5	14.9	14.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	14.0	14.9
	JDSF_X03	14.9	15.1	14.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	14.9	14.7	15.1	14.8	0.0
	JDSF_X04	14.3	14.6	14.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	14.3	14.0	14.6
Mitchell Creek	JDSF_3490	13.4	14.1	12.6	0.0	0.0	0.0	0.0	0.0	12.6	14.1	0.0	13.5	13.7	13.2	0.0	0.0
	JDSF_X02	13.7	14.2	13.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	13.2	14.2
Russian Gulch	MRC_T72	13.6	14.0	12.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	12.8	14.0
	JDSF_3501	13.1	13.1	13.1	0.0	0.0	0.0	0.0	0.0	13.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	JDSF_3502	13.2	14.1	12.6	0.0	0.0	0.0	0.0	0.0	12.6	14.1	13.0	13.1	0.0	0.0	0.0	0.0

Attachment B

DRAFT North Coast Watershed Assessment Big River Report[1]

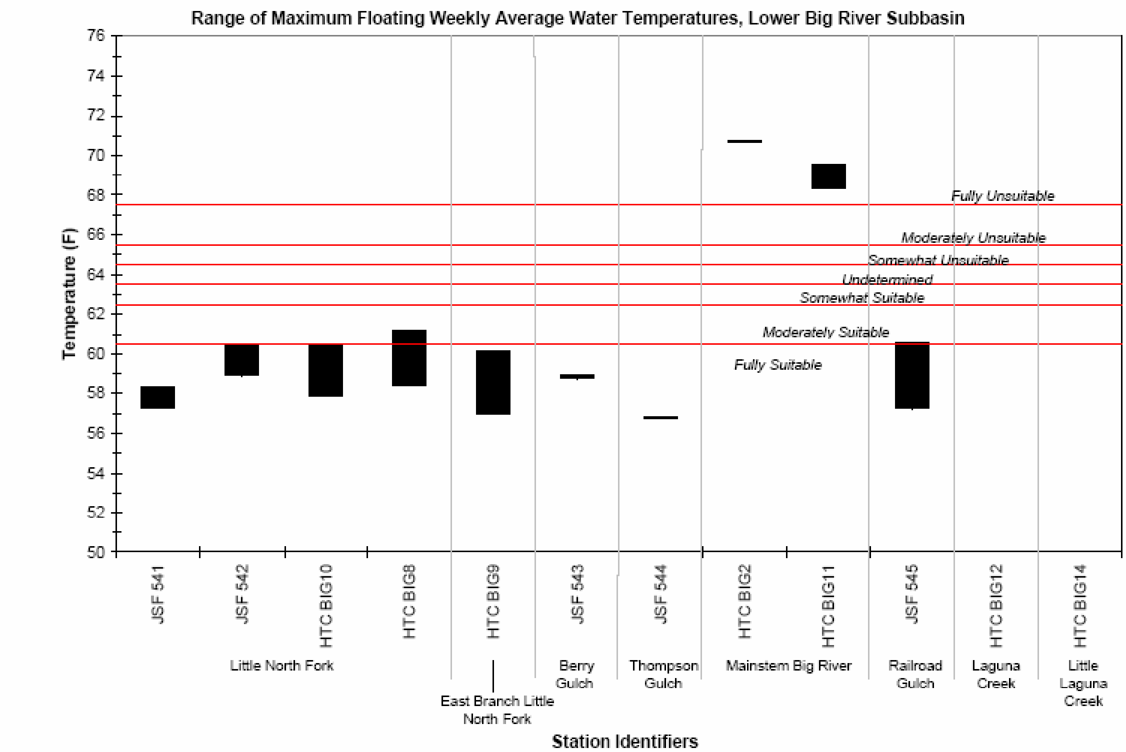
Lower Big River

Water Temperature

1. Continuous water temperature data logging devices were deployed by HTC and JSF at a total of twelve (12) locations in the lower Big River sub-watershed. In general, water temperature was monitored in one or more locations in the lower Big River watershed during the years 1993 to 2001.
2. With the exception of the temperature monitoring sites on the mainstem of the Big River (HTC BIG2, HTC BIG11), water temperatures in the Lower Big River subbasin were fully or moderately suitable. The mainstem Big River sites were fully unsuitable in all years monitored with high diurnal fluctuations (7.9-9.9˚F) and high maximum temperatures (75-76˚F).
3. Most of the Little North Fork and tributary monitoring sites exhibited low diurnal fluctuations suggesting good shading, and/or good flow conditions and/or a tempering marine influence.
4. It is probable that the Little North Fork has a cooling effect on the mainstem Big River. However, the magnitude of that effect is unknown as it is dependant on the temperature differentials and flows.

[1] North Coast Regional Quality Control Board. 2004 (preliminary draft). Big River Water Quality Assessment. Report compiled for the North Coast Watershed Assessment Program. North Coast Regional Quality Control Board, Santa Rosa. Draft utilized with permission of R. Klamt, Chief of Timber Harvest Division, North Coast Regional Water Quality Control Board.

FIGURE 4: RANGE OF MWATS, LOWER BIG RIVER SUBBASIN



Middle Big River

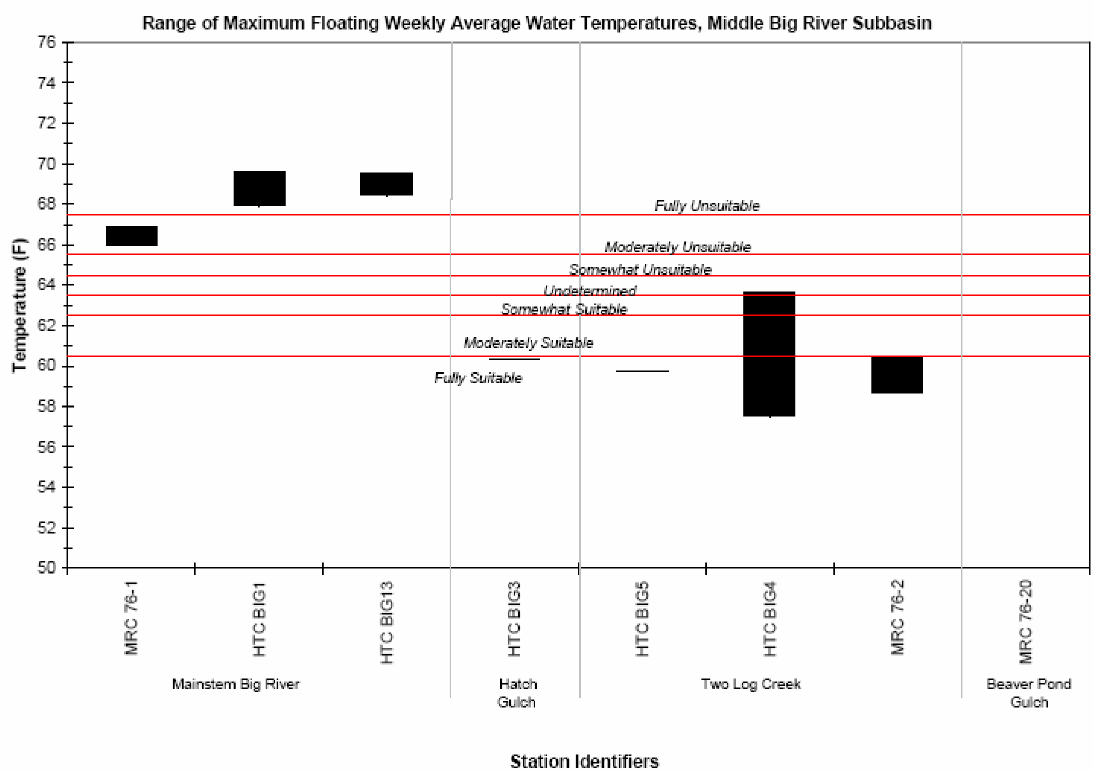
Water Temperature

1. Continuous water temperature data logging devices were deployed by HTC and MRC at a total of nine (9) locations in the middle Big River sub-watershed. With the exception of 1997, water temperature was monitored in one or more locations in the middle Big River sub-watershed during the years 1993 to 2001.
2. Data collected at the two lower Two Log Creek Sites (HTC BIG4 and MRC 76-2), indicated water temperatures between fully suitable with a minimum observed MWAT of 58˚ F and undetermined with a maximum observed MWAT of 64˚ F. Large diurnal temperature fluctuations (6.7-12.0°F) were recorded at both lower Two Log Creek sites, which may indicate poor canopy and/or low flows.
3. The only tributary to Two Log Creek that was monitored was Beaver Pond Gulch (MRC 76-20), which was monitored for one year. Based on this data, the water temperatures at this site was fully suitable with a maximum MWAT of 56°F, but based on the thermograph, it may be more representative of a thermally stratified pool or a site with a significant groundwater component.
4. A site on Hatch Gulch (HTC BIG3), a tributary to the mainstem Big River between the North Fork and Two Log Creek (but below HTC BIG1), was monitored for one year. Monitoring at this site recorded water temperatures that

were fully suitable with a maximum observed MWAT of 60ºF. The diurnal fluctuations at this site were minimal. It is likely that Hatch Gulch provides some cooling effect to the mainstem Big River.

5. All of the water temperature monitoring sites on the mainstem Big River (MRC 76-1, HTC BIG1, and HTC BIG13) had MWATs that varied from moderately to fully unsuitable (67-70˚ F) with maximum daily temperatures (73-77˚ F) in excess of the lethal limit for salmonids. High diurnal fluctuations were also recorded (7.5-12.8˚ F), suggesting poor canopy and/or low flows.
6. It is probable that Two Log Creek has a cooling effect on the mainstem Big River. However, the magnitude of that effect is unknown as it is dependant on the temperature differentials and flows.
7. In lower Two Log Creek, both MRC and HTC have temperature monitoring sites in nearly the same location. It may be more effective if one company monitored the site and shared the information with the other.

FIGURE 8: RANGE OF MWATS, MIDDLE BIG RIVER SUBBASIN

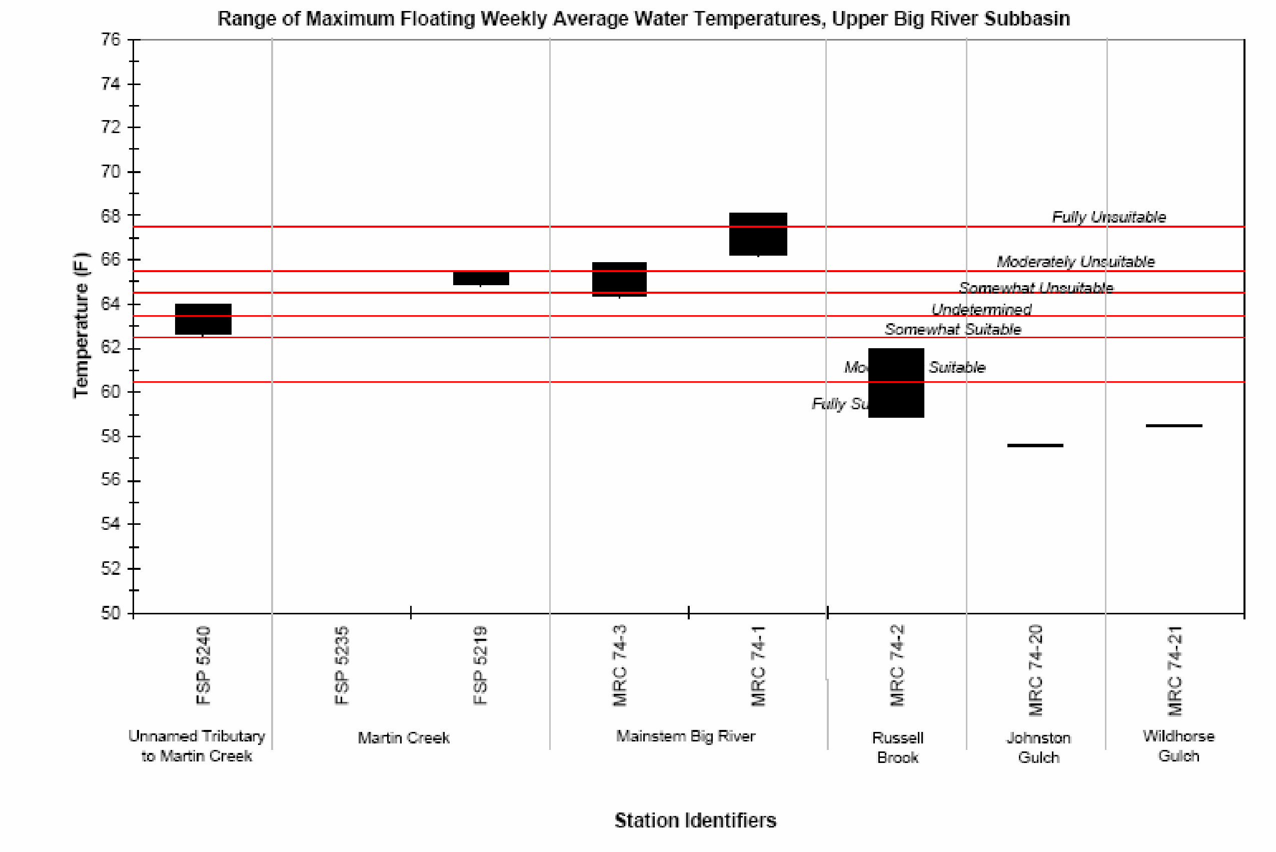


Upper Big River

Water Temperature

1. Continuous water temperature data logging devices were deployed by MRC and JSF at a total of eight (8) locations in the upper Big River sub-watershed. With the exception of 1996, water temperature was monitored in one or more locations in the upper Big River sub-watershed during the years 1990 to 2001.
2. Based on limited data from two sites in the Martin Creek watershed, the water temperatures were somewhat suitable to somewhat unsuitable with a maximum MWAT of 65˚F.
3. There are two monitoring sites on the mainstem Big River, both of which were recorded for four years. Both sites had MWATs that were undetermined to fully unsuitable with a maximum MWAT of 68˚ F. In addition, the site between Russell Brook and the South Fork Big River (MRC 74-1) had a maximum daily temperature of 75˚ F and large diurnal fluctuations of between 10.8-12.9˚ F. Several tributaries to the mainstem Big River were monitored for one to four years.
4. Russell Brook (MRC 74-2) had a maximum MWAT of 62˚ F and moderate diurnal fluctuations of between 6.7-8.4˚ F. This suggests moderate to poor cover and/or low flows and probably contributes cooler water to the mainstem Big River. The other two sites at Johnston Gulch (MRC 74-20) and Wildhorse Gulch (MRC 74-21) have MWATs that are fully suitable (58˚ F), with low diurnal fluctuations. It is likely that the temperature probes at these sites are heavily influenced by subsurface flows (groundwater).

FIGURE 12: RANGE OF MWATS, UPPER BIG RIVER SUBBASIN



North Fork Big River

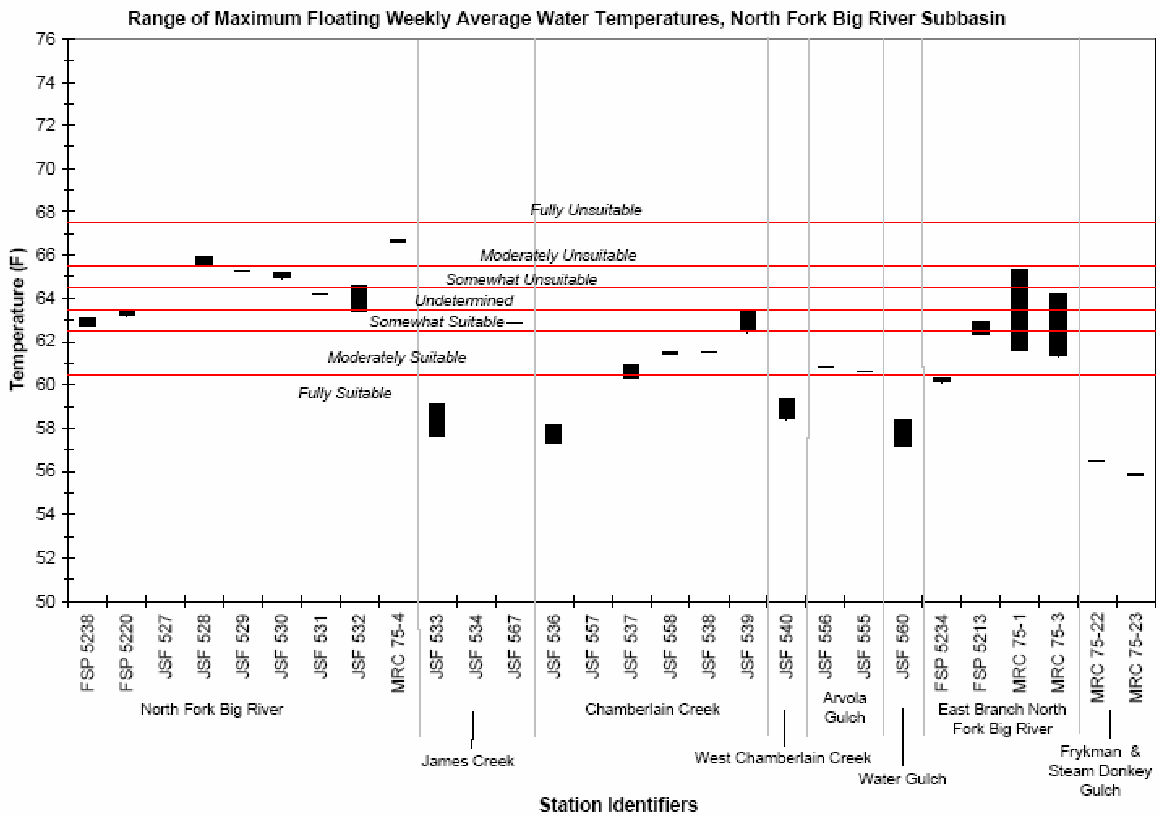
Water Temperature

1. The North Fork Big appears to heat relatively quickly upstream of, and at, the boundary of the JSF. The observed MWATs go from 63˚ F in the headwater area to 66˚F at the JSF boundary. This is likely due to poor canopy, low flows, and possibly different temperature probe placement protocols between FSP and JSF.
2. Once in JSF, water temperatures begin a steady decline. Based on temperature monitors in the North Fork on either side of the James Creek confluence and monitors in James Creek, it appears as though James Creek has a slight cooling effect on the North Fork. Recorded MWATs in the North Fork around James Creek were 65-66˚ F.
3. James Creek appears to be fully suitable at the headwaters and progressively becomes warmer until the confluence with the North Fork. The one year of monitoring near the confluence of the North Fork indicated an MWAT of 63˚F.
4. Based on temperature monitors in the North Fork on either side of the Chamberlain Creek confluence and monitors in Chamberlain Creek, it appears as though James

Creek has a cooling effect on the North Fork. Recorded MWATs in the North Fork around Chamberlain Creek were 64-65˚F.

5. Chamberlain Creek appears to be fully suitable at the headwaters and progressively becomes warmer until the confluence with the North Fork. Monitoring near the confluence of the North Fork indicated MWATs of 62-63˚F.
6. Other monitoring was conducted on several tributaries to Chamberlain Creek, including West Chamberlain Creek, Arvola Gulch, and Water Gulch. Each of these tributaries were fully to moderately suitable in the years monitored with MWATs of 57-61˚F. The thermograph from the Water Gulch site suggests that that the monitoring location may have a significant groundwater component and/or possibly a thermally stratified pool, especially in August and September. To the extent that Water Gulch and West Chamberlain Creek contribute flow to Chamberlain Creek, it is likely that they contribute some amount of cooling to Chamberlain Creek.
7. The final site in lower Chamberlain Creek (JSF 539) appears to have substantially higher water temperatures than JSF 538. Based on a 1994 Landsat vegetation map (KRIS Big River), it may be that the elevated temperatures seen at this site are due to a large clearing in this portion of Chamberlain Creek.
8. Water temperatures downstream of Chamberlain Creek and upstream of the East Branch North Fork appear to remain relatively constant, if the data from JSF 532 can be extrapolated. In any case, the MWAT at this site, it does not appear to be substantially different from JSF 531 (the site upstream of it). The MWAT in this area, with three years of monitoring, is approximately 64˚F.
9. The East Branch of the North Fork has some indication of headwaters with an MWAT of approximately 60˚ F, but with increasing water temperatures between the headwater monitoring site (FSP 5234) and the next site (FSP 5213), which had recorded MWATs of approximately 62-63˚ F in the two years of monitoring. Water temperatures appear to remain relatively constant to the mouth of the East Branch North Fork, with MWATs between 61-65˚ F.
10. Frykman and Steam Donkey Gulch, two small tributaries of the East Branch North Fork were monitored. However, while the water temperatures in both tributaries were fully suitable in the years monitored, it appears as though these temperature probes were placed in a deep stratified pool or are dominated by groundwater influences. In any case, it is unlikely that they contribute significantly to the mainstem of the East Branch North Fork.
11. Water temperatures in the North Fork below the confluence with the East Branch North Fork appears to increase significantly from what was recorded in JSF 532 (upstream of the East Branch North Fork). The maximum MWAT increases between JSF 532 and MRC 75-4 approximately 65 to 67˚F. While it does not appear the confluence of the East Branch North Fork would significantly affect water temperatures, it may be due to local conditions upstream of MRC 75-4 such as poor canopy, or just could be an artifact of the fact that MRC 75-4 was only monitored during one year, which did not coincide with the years monitored at JSF 532.

FIGURE 16: RANGE OF MWATS, NORTH FORK BIG RIVER SUBBASIN



South Fork Big River

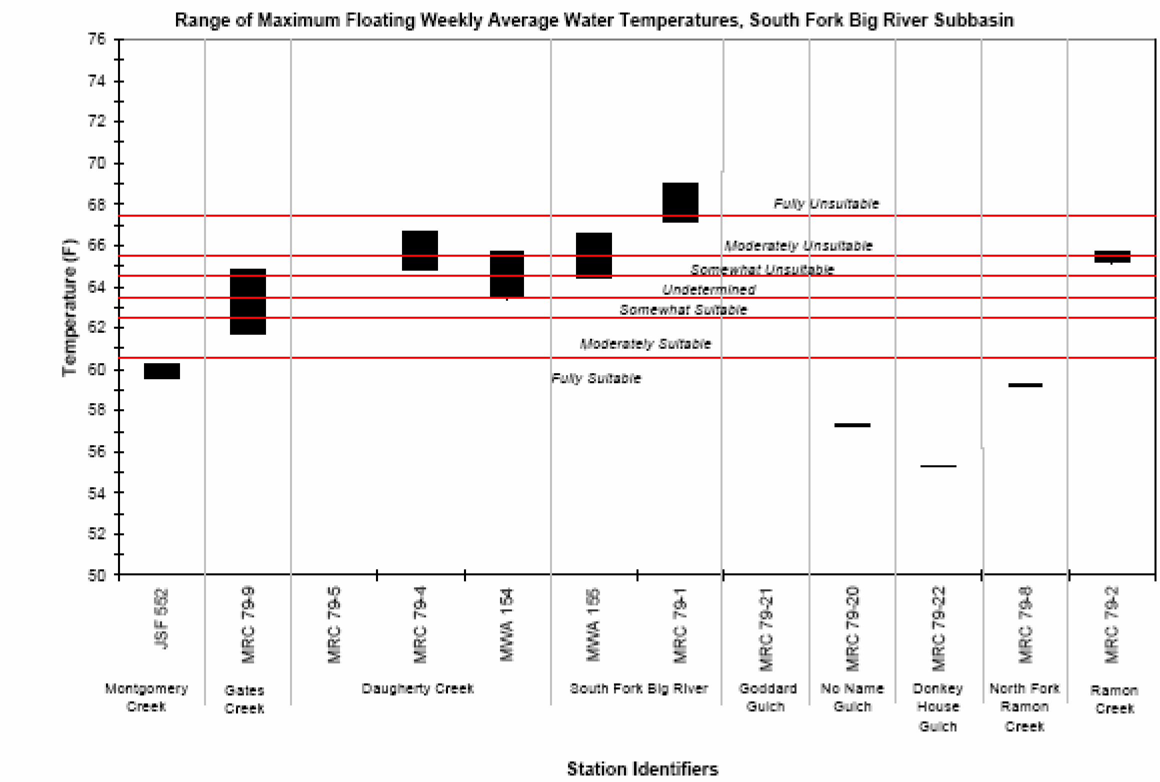
Water Temperature

1. Although upper Daugherty Creek (MRC 79-5) has only one year of data, it appears as though upper and lower Daugherty Creek (MRC 79-4) were similar in temperature with MWATs between 65-67˚ F. The other downstream site (MWA 154) appears to be generally lower than MRC 79-4, but that is to be expected as MWA places its monitoring devices in areas of thermal refugia.
2. During two years of monitoring on Gates Creek, a tributary to Daugherty Creek, MWATs of between 62-65˚ F were recorded. Based on this, it would appear that Gates Creek provides some cooling effect to Daugherty Creek.
3. Montgomery Creek (JSF 552) was within the fully suitable range at approximately 60˚F during all three years monitored. The maximum diurnal fluctuations varied between 4-5˚ F. This site is in an undisturbed location in the Montgomery Woods Reserve and is probably a good example of what can be achieved with adequate canopy in the warmer interior portion of the Big River watershed. It should be noted

that much of the interior watershed is naturally grasslands, and could not reasonably be expected to achieve these water temperatures.

4. As would be expected, the mainstem of the South Fork Big River appears to get progressively warmer as it moves towards the bottom of the watershed. However, by the time it reaches the bottom of the watershed (MRC 79-1), MWATs are generally in the fully unsuitable range as high as 69˚ F with maximum daily temperatures as high as 74˚F.
5. During the one year of monitoring water temperatures in the North Fork Ramon Creek (MRC 79-8), it appeared that it was much cooler than Ramon Creek itself (MRC 79-2), which was monitored for three years. The North Fork Ramon Creek site had a fully suitable MWAT of 59˚ F, whereas Ramon Creek downstream of the North Fork confluence had MWATs from 65-66˚F. However, it is not clear if Ramon Creek is much warmer from the headwaters and the North Fork provides only minimal cooling, or if the combined flow of the North Fork and Ramon Creek become warmer in the segment of stream below the confluence.
6. Donkey House Gulch (MRC 79-22) is a tributary to Ramon Creek, but in the one year of monitoring, it exhibited fully suitable water temperatures with an MWAT of 55˚F. Nevertheless, diurnal fluctuations in this stream appeared to indicate that the monitoring site is either in a thermally stratified pool or is dominated by groundwater. Therefore, it is expected that this would be associated with low flows and probably have little cooling effect on Ramon Creek.
7. Goddard Gulch (MRC 79-21) and No Name Gulch (MRC 79-20), both tributaries to the mainstem South Fork Big River, were each monitored for one year and had fully suitable MWATs of 57˚F. In Lower No Name Gulch, it appears though the stream was flowing until early August, at which time it may have become isolated and dominated by groundwater. This is evident by diurnal temperature fluctuations that gradually become essentially flat. Diurnal fluctuations in Goddard Gulch appeared to indicate that this monitoring site is either in a thermally stratified pool or is dominated by groundwater. Therefore, it is expected Goddard Gulch, and to a lesser degree Lower No Name Gulch would be have low flows making it unlikely that either site would have a significant cooling effect on the mainstem South Fork Big River.
8. Relatively large diurnal fluctuations in virtually all of the monitored sites indicate that throughout the South Fork subbasin there is poor canopy and/or low flows. The only exceptions to this are the monitoring sites at Montgomery Woods Reserve (JSF 552), and the sites located in gulches that are apparently dominated by groundwater. These sites were Goddard Gulch, Donkey House Gulch, and No Name Gulch.

FIGURE 20: RANGE OF MWATS, SOUTH FORK BIG RIVER SUBBASIN



Overall Summary

Water Temperature

With the exception of the Big River Estuary, continuous water temperature data loggers were available in every subbasin. Water temperatures in the mainstem Big River were high in virtually every location tested, and the daily maximum temperatures sometimes exceeded the lethal threshold for salmonids.

Tributaries in the Lower Big River subbasin had fully suitable to moderately suitable water temperatures. It is likely that this is due, in large part, to the cooling marine influence in this subbasin. Although not supported by any data, it is probable that higher precipitation in this subbasin also assists in the rapid re-growth of the forest and understory vegetation that offers stream shading. Overall, the water temperature in the Lower Big River tributaries appears to be in the best condition of any subbasin in the Big River watershed. Also, it is likely that the Little North Fork has some cooling effect as it enters the mainstem Big River.

Tributaries in the Middle Big River subbasin had fully suitable to undetermined water temperatures. While the data in this subbasin is relatively spare, it is likely that the marine influence in this subbasin and rapid re-growth of vegetation also helps keeps water temperatures relatively low. The tributaries that were monitored in this subbasin appear to be in good condition with respect to water temperature for salmonids. Also, it is likely that the Two Log Creek has some cooling effect as it enters the mainstem Big River.

Tributaries in the Upper Big River subbasin had fully suitable to somewhat unsuitable water temperatures. However, except for the site on Russell Brook and two other sites that appear to be dominated by groundwater, the tributaries that were monitored in this subbasin appear to be in poor condition with respect to water temperature for salmonids. It also appears as that the upper mainstem Big River is one of the origins of the warm water seen downstream. Water leaves this subbasin with an MWAT of roughly 66-68˚ F.

Tributaries in the North Fork subbasin, including the North Fork itself, had fully suitable to moderately unsuitable water temperatures. Generally, the tributaries that were monitored in this subbasin appear to be in good condition with respect to water temperature for salmonids. The notable exceptions to this are Lower Chamberlain Creek, most of the East Branch of the North Fork, and the mainstem of the North Fork. The mainstem North Fork is unusual in that it exhibits a rapid increase in water temperature upstream of the JSF boundary, and then slowly declines until it leaves JSF, and again shows a rapid increase near the confluence with the mainstem Big River. The obvious hypothesis is that it may be due to naturally poor canopy or to commercial timber harvesting on either end of the North Fork. In any case, this should be investigated further. It also appears as that the North Fork is one of the origins of the warm water seen downstream in the mainstem Big River. Water leaves this subbasin with an MWAT of roughly 67˚ F.

Tributaries in the South Fork subbasin, including the South Fork Big River, had fully suitable to fully unsuitable water temperatures. Except for the tributaries that appear to be dominated by groundwater and the one site in the Montgomery Reserve, the sites in this subbasin were poor with respect to water temperature. In fact, the lower mainstem South Fork had the highest daily water temperature (74˚ F) of any stream other than the mainstem Big River. Conversely, the site in the Montgomery Reserve is a good example of what can be achieved with adequate canopy in the warmer interior portion of the Big River watershed. Water leaves the South Fork subbasin with an MWAT of roughly 67-69˚F.